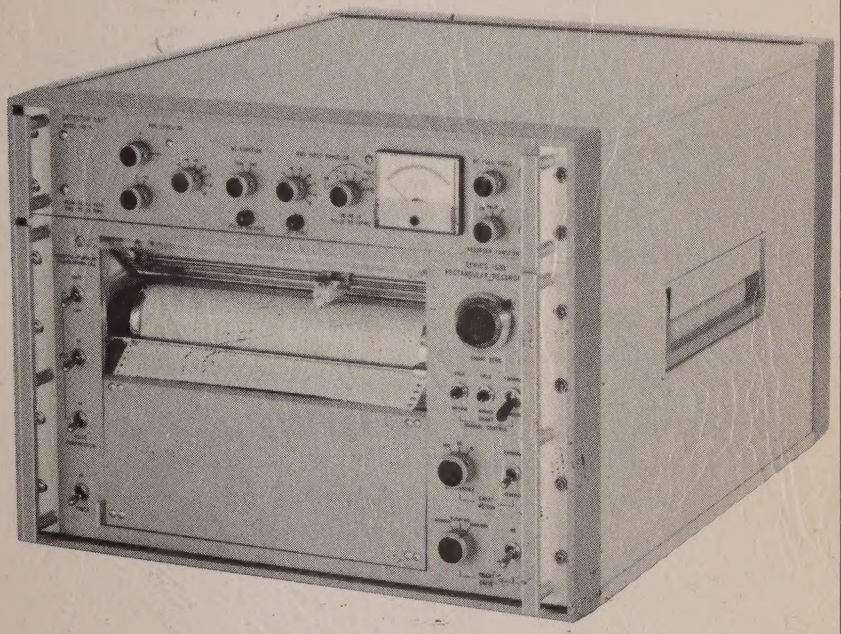
Instruction Manual

Rectangular Pattern Recorders
Series 1520



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MODEL NO. _____

SERIAL NO. _____

SERIES 1520
RECTANGULAR PATTERN RECORDERS

SCIENTIFIC-ATLANTA, INC.
P. O. Box 13654, Atlanta, Ga. 30324

Second Edition
May 1970

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CHAPTER 1
GENERAL DESCRIPTION

1.1 Introduction

The Scientific-Atlanta, Inc., Series 1520 Rectangular Coordinate Pattern Recorders permit rapid and accurate recording of a received signal. The signal is plotted as a function of the angular position of the reception or transmission device. These recorders are ideally suited for recording radiation patterns of devices whose reception or transmission varies as a function of angle, such as antennas, sound transducers, and infrared or optical devices.

A permanent recording is plotted using rectangular coordinates with signal amplitude as the Y-axis (ordinate) and the angle as the X-axis (abscissa).

To permit close examination of devices whose amplitude varies rapidly for a small angular change, the 360° angular scale (X-axis) may be expanded by means of a selector switch.

1.2 Principles of Operation

1.2.1 General

The Series 1520 Rectangular Coordinate Pattern Recorder basically consists of two high-response, closed-loop servo systems. The chart servo system positions the recording paper as a function of angular position, and the pen servo system positions a pen for recording the amplitude of the signal applied to the input of the recorder preamplifier. By insertion of the proper function potentiometer, the pen servo system automatically provides translation of the signal amplitude into either a logarithmic, a linear, or a square-root pen response.

When fed from a square-law detector or transducer, an amplitude recording may be presented as a function of received power, received voltage, or the logarithm of the received power or voltage. When fed from a linear detector or transducer, the recording may be presented as a function of the received voltage or as the logarithm of the received power or voltage.

The recorder may be furnished with either or all of the following pen functions: linear pen motion versus recorder input voltage; square-root pen motion versus recorder input voltage; logarithmic pen motion versus recorder input voltage.

The recorder will respond to an 80-db dynamic range of input signal over an 80-db logarithmic scale when fed from a linear detector, and a 40-db dynamic range of input signal when fed from a square-law detector.

To permit operation from a detector receiving an audio-modulated carrier, the recorder is furnished with a narrow-band, crystal-bolometer amplifier. When using this amplifier, the recorder and the detector constitute a sensitive video detection receiving system. The detector may be coupled directly to an antenna under test or to the output of a receiving system for improvement of the overall sensitivity.

For operation from a dc input signal, the crystal-bolometer amplifier may be replaced by an optional dc-chopper preamplifier. This permits direct recording from the output of a transducer or a detector receiving an unmodulated signal.

The chart servo system positions the chart in response to the angular position of a remote synchro transmitter which is normally mechanically linked to the device under test.

A simplified block diagram of the recorder is shown in Fig. 1.1. The recorder is composed of three sections. Each section is mounted on a standard 19-inch panel and is provided with slides to facilitate removal from the lightweight, portable instrument cabinet.

1.2.2 Chart System

Chart position data is normally obtained from either of two synchro transmitters; one geared 1:1 with the antenna or transducer positioner turntable, the other geared 36:1* with respect to the turntable. The recorder chart drive mechanism incorporates two synchro control transformers, one geared such that it makes one revolution for a 20-inch chart cycle, the other geared to give 6 revolutions for one 20-inch chart cycle.

A DEGREES/CYCLE switch permits the selection of any one of three chart-cycle ratios between the turntable and the chart drive: In the 360° position, the 1:1 synchro position information enters the chart zero differential generator. The output of the differential generator is switched to the 1:1 control transformer. When the shaft of the 1:1 control transformer is not positioned properly, an error signal is developed by the control transformer and applied to the input of the solid-state chart-servo amplifier. The

*Option S36 operates from 36:1 information only.

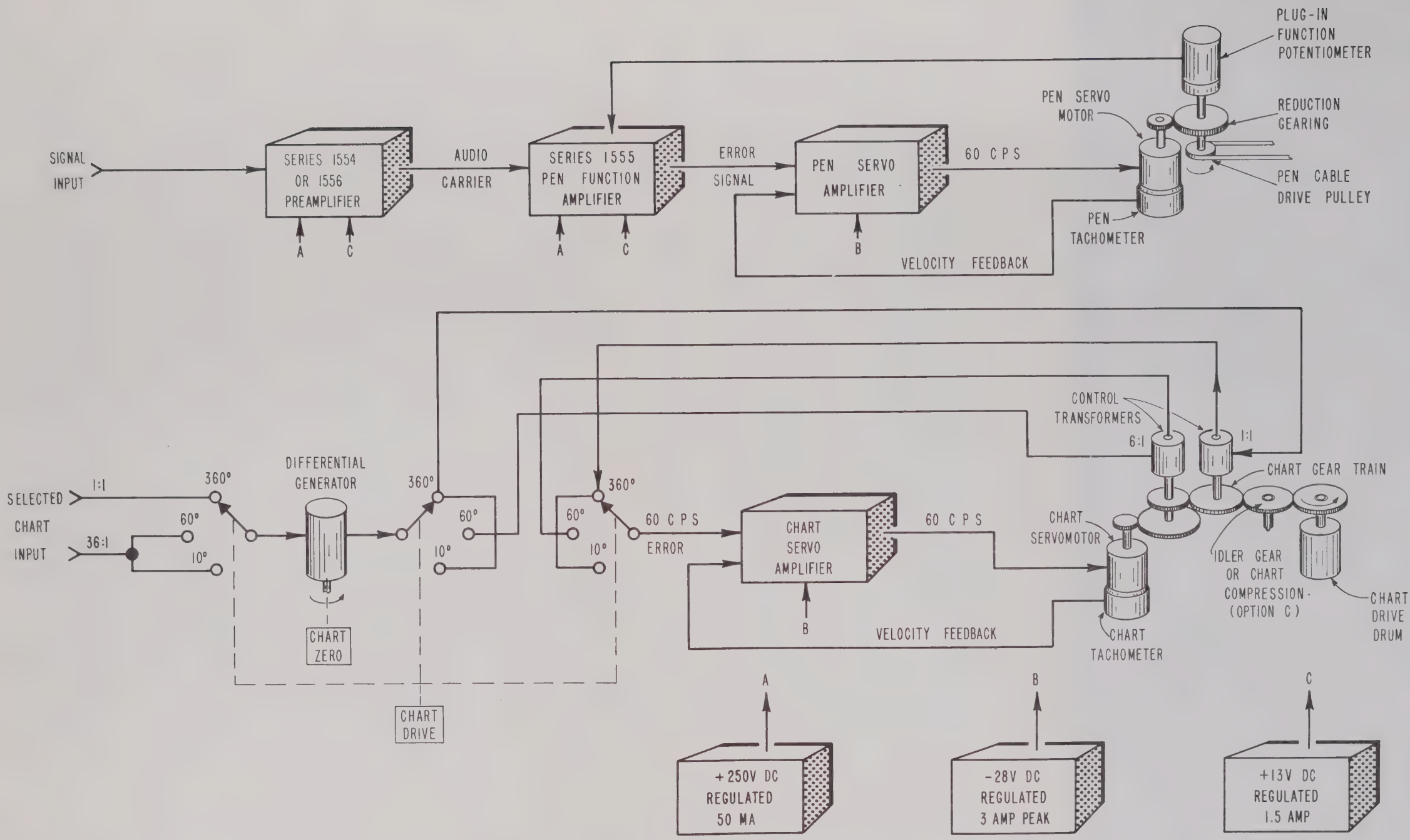

Fig. 1.1. Series 1520 Recorder Block Diagram

error signal is amplified and drives the servomotor until the control transformer and chart drum are at a zero error position. Tachometer feedback provides damping for stable servo operation. One revolution of the 1:1 turntable synchro transmitter will result in one revolution of the 1:1 chart control transformer and 20 inches of chart paper movement.

The 60° position connects the 36:1 synchro transmitter to the 6:1 chart control transformer, providing one chart cycle for 60 degrees of turntable rotation; the 10° position connects the 36:1 synchro transmitter to the 1:1 control transformer, providing one chart cycle for 10 degrees of turntable rotation.

The CHART ZERO differential generator permits alignment of the chart drum with any desired reference on the turntable.

When the S36 Option is ordered, the recorder is furnished with a third synchro control transformer (geared 36:1 with respect to one chart cycle) which provides a 360° chart cycle with a 36:1 synchro transmitter as an input. This permits operation in all three positions of the DEGREES/CYCLE switch from a single 36:1 synchro transmitter mounted to the antenna positioner turntable.

When the C Option is furnished, the recorder chart cycle may be rapidly changed from 20 inches to 8 inches to provide notebook-size recordings. The chart compression is accomplished by means of a gear-train package mounted between the control transformer gearing and the chart drive drum. Either the 8-inch or 20-inch recording can be rapidly selected by means of a mechanical gear shift. This device can either be factory-installed or installed in the field by a mechanical technician.

1.2.3 Pen System

The signal to be recorded is applied to the input of the recorder preamplifier. This preamplifier may be either the plug-in crystal-bolometer amplifier (Series 1554) normally used for video detection systems in antenna pattern recording, or a plug-in dc chopper preamplifier (Series 1556) which is used for the recording of dc signals.

When the crystal-bolometer amplifier (CBA) is used, the signal to be recorded is carrier-modulated at a fixed frequency between 500 and 2500 cps. The ac signal is greatly amplified and filtered by a filter tuned to the carrier frequency. The output of the CBA is an audio carrier which is applied to the Series 1555 Pen Function Amplifier.

When dc signals are to be recorded, the dc amplifier (DCA) chops the dc into a 400-cps carrier signal which is then amplified and filtered in a manner similar to that in the CBA.

The input to the Series 1555 Pen Function Amplifier (PFA) is a high-level, audio carrier voltage proportional to the signal input. This unit provides additional amplification and processing of the signal and furnishes a 60-cps* error signal to the pen servo amplifier. The pen servo amplifier delivers a 60-cps* output to the pen servomotor which drives the follow-up function potentiometer and recording pen to plot the required function of the signal. Tachometer (velocity) feedback provides excellent servo stability.

The plug-in function potentiometer, in conjunction with the appropriate pen function amplifier, determines the form or function in which the signal is recorded. Five plug-in models of the pen function amplifier are available, thereby permitting a pattern recorder to have a single pen function which is either linear or logarithmic, a choice of two pen functions (linear-square root or linear-logarithmic), or a choice of three pen functions (linear-logarithmic-square root).

1.3 Specifications

1.3.1 Chart System

Chart Cycle (Length)	20 inches
Chart Scale Degrees/Cycle	360°, 60°, 10°
Chart Speed (Maximum)	12 inches per second
Chart Position Error	0.02 inch static, 0.06 inch at 4 inches per second
Chart Cycle Advance and Reverse	Automatic, manual, or remote
Chart Operation (Manual)	Forward-reverse at variable speed
Chart Zero	Manual with dial readout

1.3.2 Pen System

Pen Writing Speed	60 inches per second (maximum)
Pen Lift	Manual or remote
Pen Responses Available	
Model 1521	Linear
Model 1522	Logarithmic
Model 1523	Linear-logarithmic
Model 1525	Linear-logarithmic-square root

*Supplies a 50-cps error signal if operating from an input ac line frequency of 50 cps.

Pen Response Accuracy	
Linear	±0.3% of full scale
Square-root	±0.5% of full scale, 0-40 db*
Logarithmic	±0.15 db
Pen Motor Control (On-Off)	Manual or remote
Noise Compression (Noise Improvement)	10 db referred to recorder input, 5 db referred to square-law input
Function Potentiometers	Plug-in
Dynamic Range	40 db*

1.3.3 Crystal Bolometer Amplifier Model 1554-2

	Wide Band	Narrow Band
Gain		
Crystal Input	90 db	94 db
Bolometer Input	98 db	102 db
Input Impedance		
Crystal Input	5000 ohms	5000 ohms
Bolometer Input	1000 ohms	1000 ohms
Center Frequency		
Standard 60-cps Line	1000 cps	1000 cps
Standard 50-cps Line	1025 cps	1025 cps
Bandwidth (3 db, 1000 cps)	±15 cps	±3 cps
Noise Level (200-ohm source impedance)	0.012 μv	0.006 μv
Bolometer Bias (Range)	0-15 ma	0-15 ma

Attenuation**	
Fixed	Three 20-db steps
Variable	0-20 db minimum
Attenuation Accuracy (Fixed)	±0.1 db
Dynamic Range	80 db

1.3.4 DC-Chopper Preamplifier (Series 1556)

Gain (rms ac output/dc input)	18 db minimum
Input Impedance	100,000 ohms
Chopper Frequency	400 cps
Full Scale Sensitivity (With Series 1520 and 1530A Pattern Recorders)	
Linear Pen Function	0.01 volt
Square-Root Pen Function	0.1 volt
Logarithmic Pen Function	1.0 volt

*Referred to signal input applied to a square-law detector.
**All 20-db attenuation ranges are labeled as 10-db ranges to correspond to the signal variation on the RF side of a square-law detector.

DC Input Level (Maximum)	100 volts
Noise Level (rms)	10 microvolts
DC Drift (Long Term)	50 microvolts
Recorder Pen Response (3 db)	
Large Signal	DC to 2.5 cps
Small Signal	DC to 6.0 cps
Attenuation	
Fixed	Three 20-db steps
Variable	0-20 db
Attenuation Accuracy (Fixed)	±0.1 db

1.3.5 Pen Function Amplifiers

Model 1555-1	Linear
Model 1555-2	Logarithmic
Model 1555-3	Linear-logarithmic
Model 1555-5	Linear-logarithmic-square root
Signal Level Meter Calibration (All Models)	0-15 db*

1.3.6 Plug-In Potentiometers

Model 4551	Linear
Model 4552	Linear-square root
Model 4553	Logarithmic, 40 db*
Model 4553A-20	Logarithmic, 20 db*
Model 4516-B	Logarithmic, 60 db* (used with Series 1600 Receiver)
Model 4514-B	Logarithmic, 60 db* (used with Series 402 Receiver)
Model 4553-30	Logarithmic, 30 db*

1.3.7 General

Voltage	105-125v ac
Frequency	50/60 cps
Power	200-250 watts
Weight	100 pounds

*Referred to signal input applied to a square-law detector.

CHAPTER 2
INSTALLATION AND OPERATION

2.1 Installation

Series 1520 Recorders are normally shipped with the subassemblies packed in separate containers to prevent damage. However, in some console arrangements, you may receive a pre-assembled unit. In either case, carefully inspect each item for damage which may have occurred during shipping. If any damage is found, notify the carrier and your local Scientific-Atlanta sales representative at once.

Before operating the recorder remove all packing material and check all ventilating fans for freedom of rotation.

2.1.1 Installation of Units Requiring Assembly

(a) Insert the power supply and servo amplifier unit in the top rear compartment of the cabinet. Slide the unit in, but do not fasten the panel.

(b) Insert the mechanical head in the lower front compartment and slide in. Do not fasten.

(c) Connect the interconnecting cables as shown in Fig. 7.1. Be certain that the proper connections are made to the pen function amplifier and the crystal-bolometer amplifier subunits. It is not necessary to remove the slide-mounted shielded case for access to these units.

(d) After rechecking the connections, make a quick visual examination of each subunit to make certain that nuvistor and vacuum tubes are properly seated.

2.1.2 Signal Inputs

2.1.2.1 Chart System Input: A Scientific-Atlanta Series 4300 Synchro Transmitter Unit or its equivalent should be used to furnish synchro data for the chart system. This unit should be mechanically coupled to the required axis of the antenna positioner. The recorder has three input connectors and a CHART DRIVE switch to permit front-panel selection of any one of three synchro sources.

Connections from each synchro transmitter unit require an 8-conductor cable fitted with Amphenol Type MS3106A-20-7S and MS3106A-20-7P cable connectors.

Before energizing the synchro system, the proper size of fuse must be installed in the "Synchros" fuse holder in the recorder head. Check the table below to find the fuse size to use with the total number of external synchros. Remove the Phillips head screws that hold the recorder head in the cabinet and slide the head out to expose the adjustment panel at the top left front. Install the required fuse in the fuse holder for A3F1 (Synchros). Slide the head back in and secure it.

EXTERNAL SYNCHROS	A3F1 (SYNCHRO) 3AG	
	50 cps	60 cps
2	3/4a	1/2a
4	1-1/2a	1a
6	2-1/2a	1-1/2a
8	3a	2a

Fuse sizes based on 0.20a/synchro at 60 cps,
0.32a/synchro at 50 cps

Table 2.1. Synchro Fuse Sizes

Early versions of the recorder were wired with the S3 leads of the external synchros common and connected to pin H of each synchro input connector. Later versions are wired with the S2 leads as common and connected to pin H.

The external synchros to be used with the recorder can use any stator-common arrangement, but the common line must be connected to pin H of the synchro input connector. Refer to Figs. 7.2 and 7.4 for further information.

2.1.2.2 Pen System Input: The output from a crystal or bolometer detector is connected to the input connector of the crystal-bolometer amplifier. If a bolometer is used, the BOLOMETER CURRENT adjustment should be turned fully counterclockwise before connecting the bolometer. Set the INPUT switch to the BOLOMETER position and the pen function amplifier METER FUNCTION switch to the BOLOMETER CURRENT position while adjusting the bolometer current. After adjustment, turn the METER FUNCTION switch to the OFF or another position to eliminate noise caused by mechanical vibration of the meter movement.

For operation from a crystal detector, set the INPUT switch to the CRYSTAL position, and the BOLOMETER CURRENT adjustment fully counterclockwise.

When the recorder is furnished with a dc chopper preamplifier or a special preamplifier, refer to the appropriate preamplifier instruction manual for input connections and requirements.

The available recorder pen functions are determined by the pen function amplifier and plug-in potentiometers furnished. For a given pen function, it is essential to use the proper amplifier and potentiometer (refer to paragraphs 1.3.5 and 1.3.6).

2.2 Chart System Controls

The recorder head contains the controls for operation of the chart system. These controls and their operational functions are described below.

CHART DRIVE--This toggle switch allows the chart drive motor and paper roll takeup to be turned off when not in use.

CHART DRIVE (AZIMUTH, ELEVATION, and AUXILIARY)--This switch permits the selection of any of three separate chart-positioning inputs.

CHART MOTION (FORWARD-REVERSE)--The direction of motion of the chart roll with respect to the rotary direction of the positioner turntable (or synchro transmitter) may be reversed with this switch.

CHART MOTION (DEGREES/CYCLE)--This switch permits the rapid selection of one of three chart scales, each having the indicated total number of degrees of positioner rotation per chart cycle. The S36 Option recorders have an alternate 360° chart cycle position (360°A) which permits recording with only 36:1 synchro information.

CHART MANUAL CONTROL (FORWARD-REVERSE)--This lever switch permits manual positioning of the chart in either the forward or reverse direction. The speed of chart rotation is adjusted with the Forward and Reverse Speed potentiometers located on the service control panel inside the recorder head. These controls also determine chart speed during automatic chart cycle advance and reverse modes.

CHART CYCLE (ADVANCE and REVERSE)--Depressing the CHART CYCLE-ADVANCE button causes an automatic advance of the chart roll by exactly one cycle (20 inches), permitting rapid advance of the chart for a new recording. The pen is automatically lifted during the cycle. The CHART CYCLE-REVERSE button provides the same action in reverse. The ADVANCE button may be pressed to override the REVERSE action in the event the REVERSE button is depressed and there is insufficient chart paper in front of the drum to allow a complete reverse cycle.

CHART ZERO--Adjustment of this knob permits positioning the chart roll with respect to the positioner turntable. A calibrated readout allows the operator to reset the

chart drive to any reference position, and provides a direct indication of chart reference change when switching to the 10° and 60° chart cycle positions. A locking lever is provided on the CHART ZERO control knob to maintain dial settings (also see paragraph 2.6).

For remotely controlled chart operation, see paragraph 2.10.

2.3 Pen System Controls

The operation of the pen system is determined by controls located on the front panel of the pattern recorder head and controls located on the front panel of the plug-in preamplifier and pen function amplifier. For a detailed description of the controls located on the crystal-bolometer amplifier or the dc-chopper preamplifier, refer to the separate instruction manual furnished with that particular unit.

2.3.1 Recorder Head Controls

PEN (ON)--This switch permits the pen drive motor to be turned off when recording is not desired. The pen motor should be turned off when cable connections affecting the pen position are being made and when recording is not desired. The life of the function potentiometers can be increased by not allowing the pen to idly follow random noise signals for long periods of time.

PEN (LIFT-WRITE)--This switch permits the pen to be lifted from the chart writing surface when ink recording is not required. The pen should be lifted when positioning or replacing the chart and when it is necessary to refill or replace the pen.

NOISE COMPRESSION--When this switch is ON, the magnitude of recorded noise is reduced by narrowing the pen servo system bandwidth. It should only be used when sensitivity is at a premium. As much as 5 db of noise reduction is possible; however, the pen dynamic error is increased requiring that slower recording rates be used. Static error is not effected.

For remotely controlled pen operation, see paragraph 2.10.

2.3.2 Pen Function Amplifier Controls

PEN FUNCTION (LOGARITHMIC-LINEAR-SQUARE ROOT)--This switch selects the form of signal recording desired. The logarithmic and linear pen function amplifiers do not have a PEN FUNCTION switch, as they are single-function amplifiers.

METER FUNCTION--The meter on the pen function amplifier may be used to monitor either the received signal or bolometer current.

The 0 DB and 20 DB positions provide coarse signal attenuation during monitoring.

METER GAIN--This control permits fine control of the meter sensitivity.

PEN ZERO--This adjustment permits setting the zero signal input level for the linear and square-root modes. The logarithmic mode does not require zero adjustment.

2.4 Removal and Installation of Plug-In Potentiometer

The pen function potentiometers may be plugged in rapidly from the front, or from the top with the rectangular recorder head removed from the cabinet. The POWER switch should be off before attempting to change potentiometers.

To remove the plug-in potentiometer, lift the front access door and remove the chart paper roll. Disconnect the cable from the potentiometer to the recording head. Grasp the body of the potentiometer, rotate it counterclockwise until it strikes the stop, then pull out.

Before inserting the new potentiometer, gently push the pen to the full-scale stop position (far right) with the forefinger.

Rotate the pickup arm on the potentiometer until it is centered between the two small reference holes (see Fig. 2.1). Insert the potentiometer into the pilot block on the mechanical head assembly and slowly rotate it clockwise while maintaining a slight forward pressure. The potentiometer will contact the spring retainers which hold it in position. Continue rotating clockwise until the potentiometer locks against the clockwise stop. Connect the potentiometer cable.

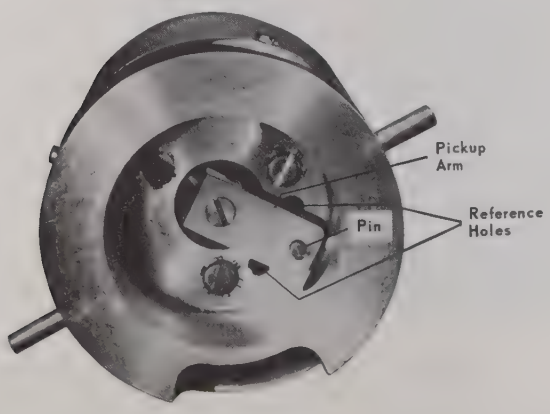

Fig. 2.1 Potentiometer Pickup Arm Positioning

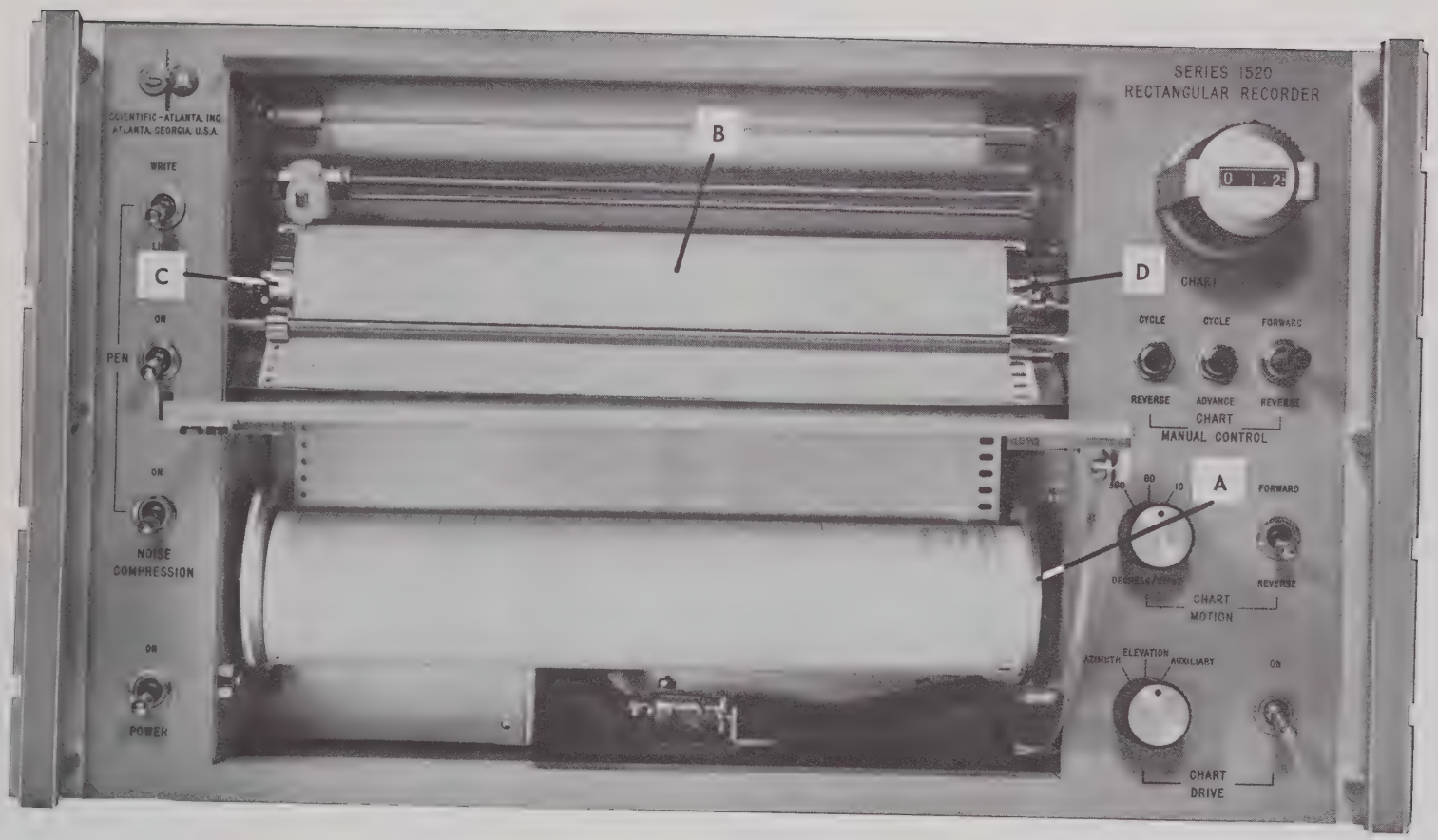

Fig. 2.2 Chart Paper Installation

2.5 Loading Chart Paper

When installing a new chart roll in the pattern recorder, orient the paper roll with the paper rolling off the top of the roll toward you. Open the doors of the recorder head and seat the hole at the right-hand end of the paper roll core over the hub of the disc (A, Fig. 2.2) located at the right of the paper roll compartment. Push the chart roll and disc to the right and align the hole at the left-hand end of the paper roll core with the hub at the left of the paper roll compartment. Relieve the pressure to the right and rotate the left-hand disc until the key is aligned with the slot in the left-hand end of the paper roll core. Pull the roll to the left until it is firmly seated against the left-hand disc.

Tear off both corners of the end of the chart to form a point at the center and feed the paper behind the chart drive cylinder (B, Fig. 2.2) until the point on the chart can be pulled over the top of the cylinder. Pull the paper through and feed the sides under the hold-down clips (C and D, Fig. 2.2). Continue to pull the paper slowly until the holes at each end of the paper are firmly seated over the sprockets. If necessary, lift the hold-down clips out of the way to aid in seating the paper symmetrically over the sprocket.

Pull out a small amount of paper, close the door to the writing compartment, and tear off the paper. For a clean tear, hold the paper near the left end and tear up with an even motion.

Before turning the chart system on, be certain that at least 10 inches of paper have been threaded over the chart drum. This will prevent the chart system from pulling the end of the chart back into the recorder during initial synchronizing.

2.6 Chart Registration

To maintain a chart reference with respect to the positioner, the chart paper sprocket hole directly below the 0° mark on the chart paper should be placed over the sprocket pin marked with a dot on the left end of the chart drive cylinder (see Fig. 2.3). Swing the hold-down clips out of the way during registration alignment. The chart can then be adjusted with respect to the positioner or antenna boresight axis with the CHART ZERO control.

Once the chart has been properly referenced or registered, the number on the chart zero dial should be recorded. If more than one chart scale is to be used, record the paper chart zero readout in each chart cycle position. Registration can be maintained during paper roll changes by rotating the positioner to its approximate zero position.

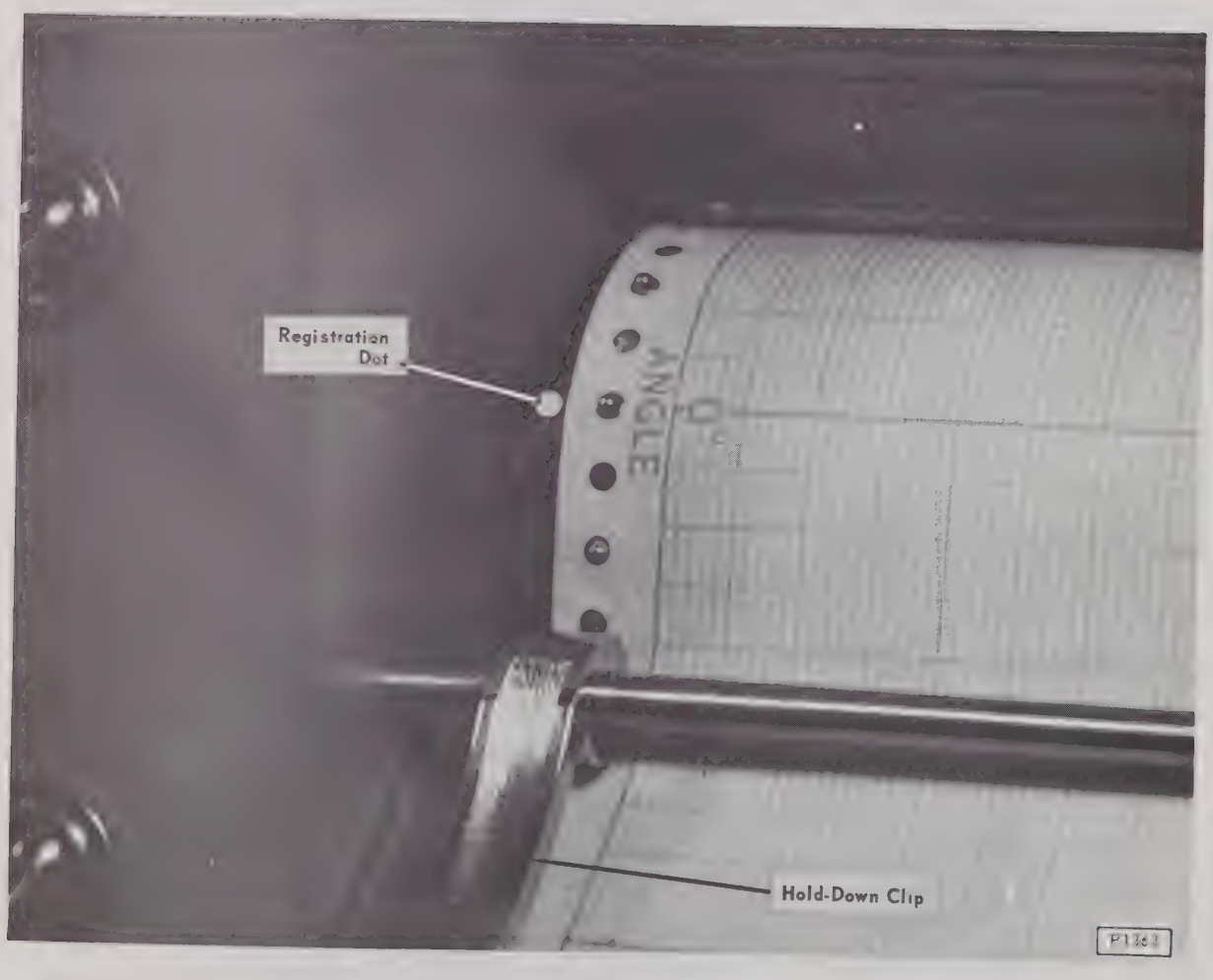

Fig. 2.3. Chart Registration

(within 1 or 2 degrees of boresight zero is quite adequate, even on the 10° chart scale). When the dot on the registration disc comes into view, stop rotation and drop the chart paper "zero" sprocket hole on the dot-coded sprocket pin.

2.7 Chart Compression

When Option C is ordered*, two chart-cycle lengths are available--the standard 20-inch cycle and an 8-inch page-size cycle. The shift from one length to the other is performed with a swinging gear-train assembly located on the left end plate of the recorder.

To change cycle lengths, remove the eight screws that secure the head in the cabinet and slide the head out far enough to expose the gear-shifting mechanism (approximately half way).

Loosen the two plated, knurled thumbscrews and rotate the gear-train assembly as far as possible to the desired position (see Fig. 2.4). The slot in the plate must be firmly seated on the thumbscrew shaft.

Tighten the thumbscrew.

Be careful not to disturb the chart drive gear or the larger gear to the left of the gear-shifting mechanism; the chart registration previously set will be inaccurate if the gears are moved.

2.8 Operating Instructions

(a) Load chart paper and install appropriate plug-in potentiometer (see paragraphs 2.4 and 2.5).

(b) Apply proper synchro and signal inputs (see paragraph 2.1.2). Be certain the INPUT switch is in the appropriate position. Turn the BOLOMETER CURRENT adjustment fully counterclockwise.

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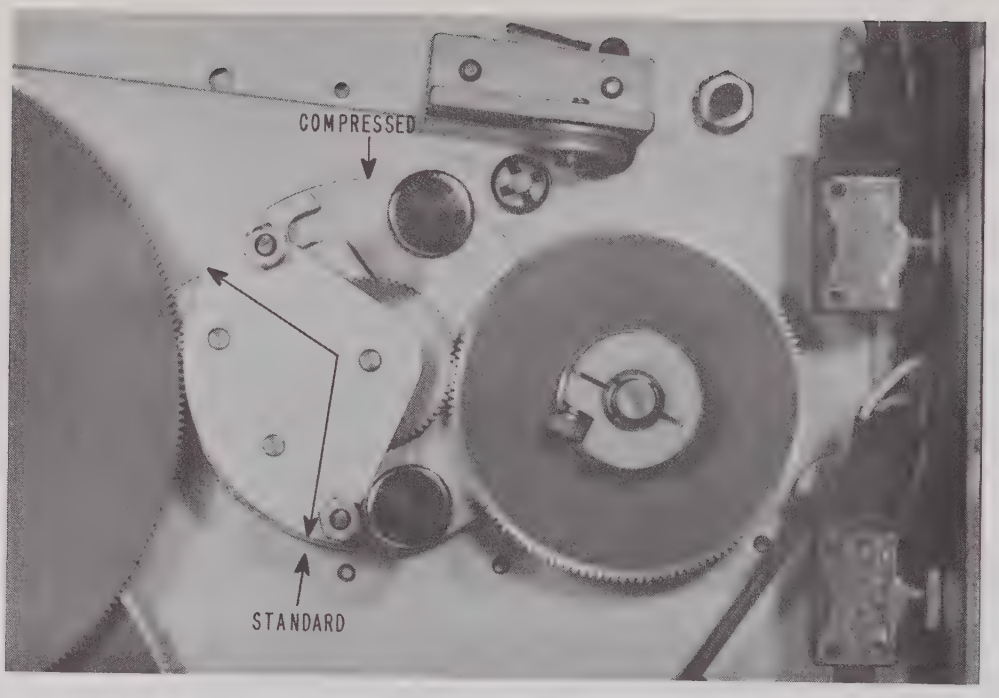
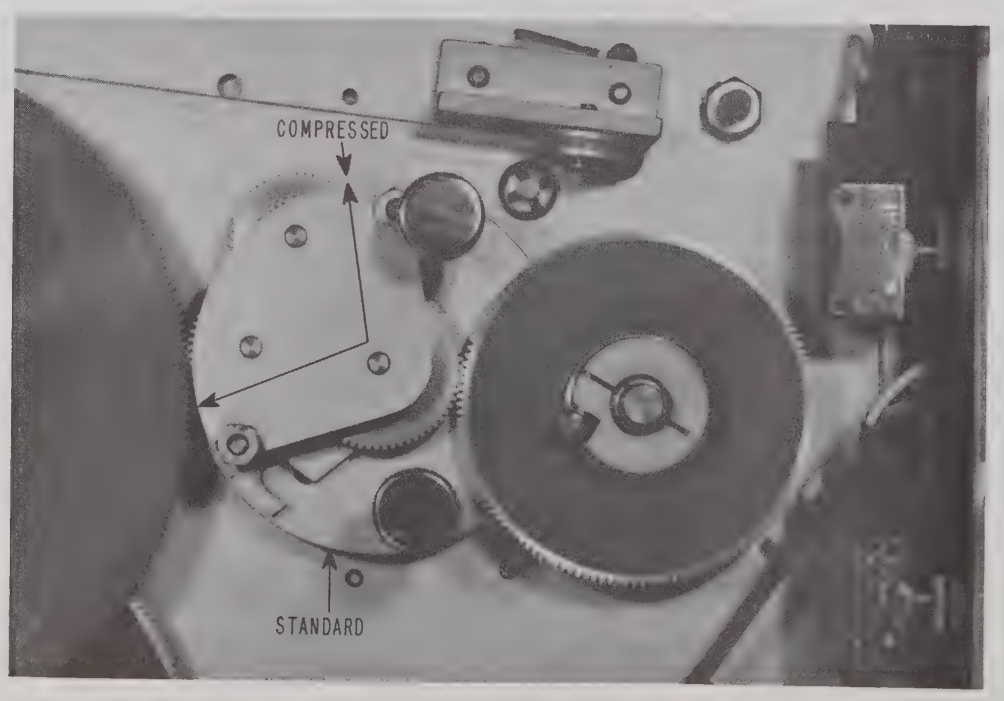
*Option C can be installed in the field; see paragraph 5.9.



Standard



Compressed

Fig. 2.4. Chart-Cycle Shifting Mechanism

(c) Select the required pen and chart functions. The pen function should correspond to the plug-in potentiometer used (see paragraphs 1.3.5 and 1.3.6).

(d) Install the pen in the pen carriage.

(e) Turn the POWER switch ON.

(f) Move the METER FUNCTION switch to BOLOMETER CURRENT and set the BOLOMETER CURRENT adjustment to the proper current level.

(g) Return the METER FUNCTION switch either to one of the SIGNAL positions, or to OFF.

(h) Turn the PEN switch ON.

(i) Place the PEN LIFT-WRITE switch in the WRITE position.

(j) If a crystal-bolometer amplifier is used, be certain that the modulation frequency is tuned to the center frequency of the CBA by peaking the pen response by use of the signal-level meter. (Also see Model 1556 DC Amplifier Instruction Manual.)

(k) Adjust the preamplifier attenuator controls for full-scale pen deflection with the antenna or transducer angularly adjusted for maximum input signal.

(l) If the meter is used for signal monitoring, use the 0 and 20 DB positions and the METER GAIN control to adjust to meter full scale (0). A scale overlap is provided.

(m) The desired chart cycle expansion and chart direction should be selected before recording.

(n) When recording in the linear and square root modes, rotate the preamplifier attenuator fully counterclockwise and set the pen to zero with the PEN ZERO adjustment.

The recorder is now ready for recording.

2.9 Remote Control

The following functions can be remotely controlled:

(a) Pen lift-write
(b) Pen motor on-off
(c) Chart motor on-off
(d) Chart cycle advance-reverse.

Fig. 2.6 shows the circuit for a suggested remote operating panel.

For remote operation, the following recorder controls must be set as shown:

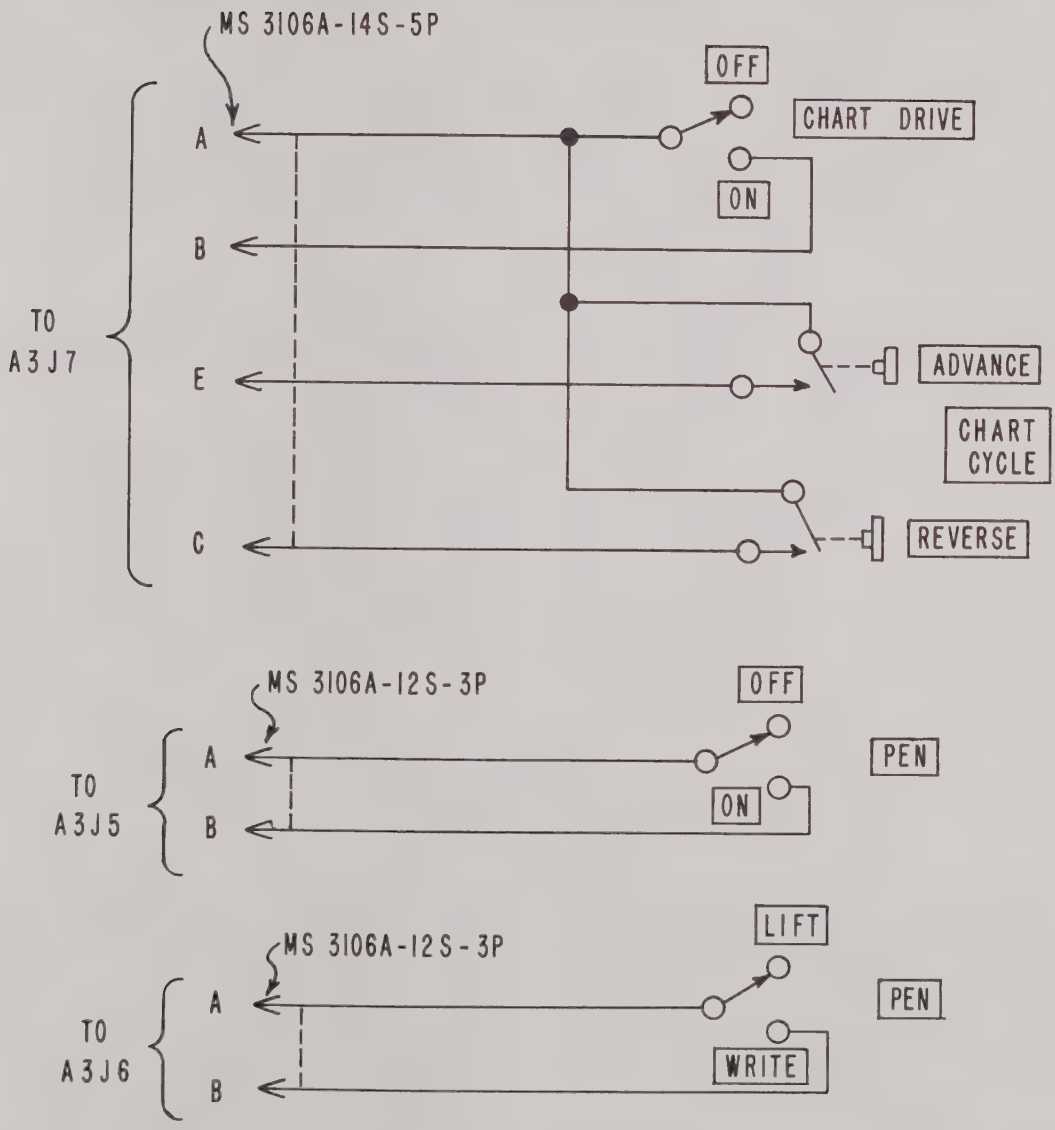
LIFT-WRITE	LIFT
PEN	OFF
CHART DRIVE	OFF

2.10 Operational Notes

(a) Connection of the ground wire provided in the power cord to a zero-potential buss is always recommended to minimize shock hazard and radio-frequency interference from other equipment. In certain console arrangements, where ground returns are already provided, the power cord ground need not be used.

(b) Dual grounds (particularly on the signal-input leads) which can cause ground-loop currents should be avoided. One prime symptom of ground-loop currents is gross pen standoff from the bottom, even with the input signal off. The pen sometimes exhibits a fast beat or sinusoidal oscillation at a high frequency. This should not be confused with normal noise standoff encountered only during maximum gain settings when a crystal-bolometer amplifier is used. A common source of ground-loop potential is the detector mount which is accidentally grounded to the antenna positioner structure. If the loops cannot be completely broken, use of the TRIAXIAL GROUND connector on the front panel will greatly minimize the ground-loop effects. In some cases, using the narrow-band mode of the crystal-bolometer amplifier will minimize ground-loop effects.

(c) Interference from other antenna pattern ranges operating at approximately the same modulation frequency can sometimes be minimized or eliminated by use of the crystal-bolometer amplifier narrow-band



NOTE: ALL CONDUCTORS NO. 20 AWG.

5

Fig. 2.6. Schematic Diagram of Suggested Remote Operating Panel

mode. The center frequency of the crystal-bolometer amplifier is determined by dual plug-in filters. Filters are available at any frequency between 500 cps and 2500 cps. Modulation frequency should be periodically checked by adjusting the modulation for maximum pen deflection.

(d) Always place the INPUT switch in the proper position. Be certain the BOLOMETER CURRENT adjustment is fully counterclockwise before inserting a new bolometer. Do not leave the METER FUNCTION switch in the BOLOMETER CURRENT position while recording.

(e) Two pattern recorders may be operated from a single bolometer detector. This procedure is described in the crystal-bolometer amplifier instruction manual, paragraph 2.4.

(f) The average life of the plug-in balance potentiometer is two million cycles. When not recording, the pen motor should be switched off, especially if the noise level is high. Use the signal level meter in the pen function amplifier as a level indicator when recording is not desired. This will greatly increase potentiometer life.

(g) The step attenuator located on the crystal-bolometer amplifier front panel may be used to obtain accurate antenna patterns exceeding a 40-db dynamic range. This is particularly useful in examining side lobes and nulls of a pattern.

(h) Use the noise-compression circuit to observe side lobes that are obscured by noise. Do not use the noise-compression circuit when noise-level reduction is not required.

(i) Use the PEN LIFT switch to prevent inking when recording is not required.

(j) Insertion of a chart in the recorder is simplified by tearing off the corners of the paper to provide a point for threading.

(k) The pen rail should be wiped clean once every week, or more often, depending on atmosphere and dust conditions. The pen carriage has lead-Teflon bearings and should be lubricated as described in paragraph 5.8. The upper door should be kept down to minimize the amount of dust entering the recording head.

(1) The slide switch on the rear of the pen function amplifier should always be in the Int. position. The Ext. position is used with a power-normalizing accessory that will be available in the near future.

CHAPTER 3
DETAILED DESCRIPTION

3.1 Construction

The Series 1520 Rectangular Pattern Recorders are constructed to provide maximum circuit accessibility to facilitate maintenance and adjustment while providing adequate electrostatic and magnetic shielding between sensitive circuits and sources of electric and magnetic fields. Particular attention has been given to interconnecting ground circuits to prevent inter-unit coupling caused by ground loops (see Fig. 3.1).

All major assemblies of the recorder are designed for mounting on rack slides, and most of the recorder circuits are accessible from the top when a chassis is in the extended position. All variable components which require only occasional adjustment are provided with lock nuts and are arranged to be accessible from the top of the chassis.

Both the sensitive preamplifier and the pen function amplifier are plug-in units housed in a shielded rack-mounted assembly when in position. They are supplied with regulated dc filament and B+ voltages from the power supply and servo amplifier unit.

The balance potentiometers used with the pen system are housed in self-aligning plug-in cases which allow rapid replacement without the necessity of adjustment.

To aid in the identification of components in the recorder, the major subassemblies have each been assigned a prefix number as follows:

Prefix	Subunit
A1	Crystal-Bolometer Amplifier* and/or DC Amplifier*
A2	Pen Function Amplifier
A3	Recorder Head
A4	Servo Amplifier and Power Supply

For example, capacitor A4C5 is located in the power supply and servo amplifier unit. Resistor A2R38 is located in the pen function amplifier.

3.2 Preamplifiers

The plug-in preamplifier furnished with the rectangular recorder may be either a

*See paragraph 3.2.

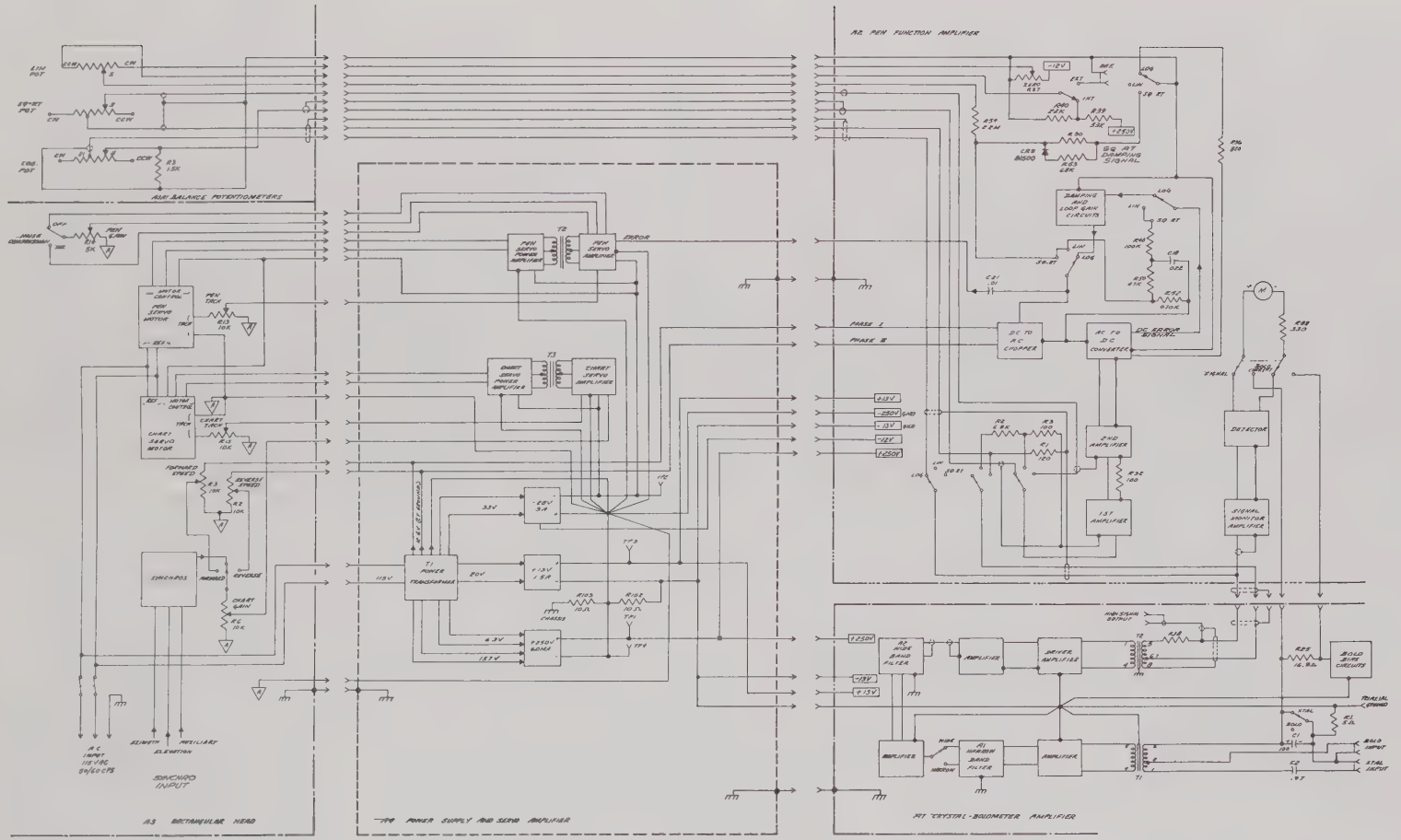


Fig. 3.1. Recorder Grounding System

crystal-bolometer amplifier, a dc-chopper preamplifier, or both. The crystal-bolometer amplifier permits the recorder pen system to be directly driven from an audio voltage or from a crystal or bolometer detector receiving an audio-modulated RF carrier. For operation from a crystal detector receiving an unmodulated RF carrier, or from a direct dc input, the dc-chopper preamplifier must be used. This amplifier employs a mechanical chopper to convert an input dc voltage to a 400-cps carrier. The carrier is fed through a narrow-band amplifier to provide noise rejection.

A complete description of the crystal-bolometer amplifier and the dc-chopper preamplifier will be found in separate instruction manuals provided with those units.

3.3 Pen Function Amplifier

The pen function amplifier is a plug-in unit which provides the necessary amplification and switching to generate one or more recorder pen functions. Four models of this unit are available permitting a wide selection of pen function combinations. The model numbers and pen functions are given in paragraph 1.3.5.

It will be helpful to refer to the simplified diagrams in Fig. 3.2 while reading the discussion that follows; complete pen function amplifier schematic diagrams are located in Chapter 7.

3.3.1 Theory of Operation

3.3.1.1 Linear Function: The circuit arrangement for a linear pen function is shown in Fig. 3.2A. It is desired to provide a recorder pen displacement P which is directly proportional to the amplitude of the input signal E_s. The quantities shown in Fig. 3.2A are as follows:

E_s	Input signal
A	Amplifier gain
$-E_d$	AC-DC converter amplifier output
E_b	Reference voltage
E_r	Potentiometer arm potential
e_d	DC error signal
e_a	AC error signal
P	Recording pen displacement

The equations which describe the circuit operation are

$$-E_d = AE_s \tag{1}$$

and

$$E_r = PE_b. \tag{2}$$

With the high-gain servo loop continually adjusting E_r to balance $-E_d$ (maintaining the error signal e at minimum or zero), then,

$$E_r = E_d. \tag{3}$$

Substituting PE_b for E_r, and AE_s for E_d gives

$$PE_b = AE_s. \tag{4}$$

Since A and E_b are constants,

$$P = KE_s. \tag{5}$$

3.3.1.2 Square-Root Function: The circuit arrangement for square-root pen function is shown in Fig. 3.2B.

In this case, it is desired to provide a recorder pen displacement P which is directly proportional to the square-root of the amplitude of the input signal E_s. The quantities shown in Fig. 3.2B are as follows:

E_s	Input signal
E_i	Amplifier input
R	Linear potentiometer resistance
R_l	Load resistance
A	Amplifier gain
$-E_d$	AC-DC converter output
E_b	Reference voltage
E_r	Potentiometer arm potential
e	Error signal
P	Recording pen displacement

The equation which describes the circuit operation is

$$E_i = \frac{E_s R_l}{R_l + PR}. \tag{6}$$

If $R_1 << PR$, which is accomplished over the desired range of P by making R large and R_1 small, then

$$E_i = \frac{E_s R_1}{PR} \tag{7}$$

$$E_d = AE_i \tag{8}$$

$$E_d = \frac{AE_s R_1}{PR} \tag{9}$$

$$E_r = PE_b \, . \tag{10}$$

With the high-gain servo loop continually adjusting E_r to cancel $-E_d$ (maintaining the error signal e at minimum or zero) then

$$E_r = E_d \, . \tag{11}$$

Because the two linear potentiometers are mechanically ganged, the pen displacement is common to both. Substituting PE_b for E_r and $\frac{AE_s R_1}{PR}$ for E_d gives

$$PE_b = \frac{AE_s R_1}{PR} \, . \tag{12}$$

$$P^2 = \frac{AE_s R_1}{RE_b} \, . \tag{13}$$

Since $\frac{AR_1}{RE_b}$ is constant,

$$P = K \sqrt{E_s} \, . \tag{14}$$

3.3.1.3 Logarithmic Function: The circuit arrangement for logarithmic pen function is shown in Fig. 3.2C. In this case, it is desired to provide a recorder pen displacement P which is directly proportional to the logarithm of the amplitude of the input signal E_s. The quantities shown in Fig. 3.2C are as follows:

E_s	Input signal
E_i	Amplifier input
A	Amplifier gain
$-E_d$	Amplifier output
E_r	Reference voltage
e	Error signal
P	Recording pen displacement

The equations which describe the circuit operation are

$$E_i = \frac{E_s}{\log^{-1} P} \tag{15}$$

and

$$E_d = \frac{AE_s}{\log^{-1} P} \cdot \tag{16}$$

With the high-gain servo loop continually adjusting $-E_d$ to cancel E_r (maintaining the error signal e at minimum or zero) then,

$$E_r = E_d \tag{17}$$

Substituting $\frac{AE_s}{\log^{-1} P}$ for E_d gives

$$E_r = \frac{AE_s}{\log^{-1} P} \tag{18}$$

$$P = \log \frac{A}{E_r} + \log E_s \tag{19}$$

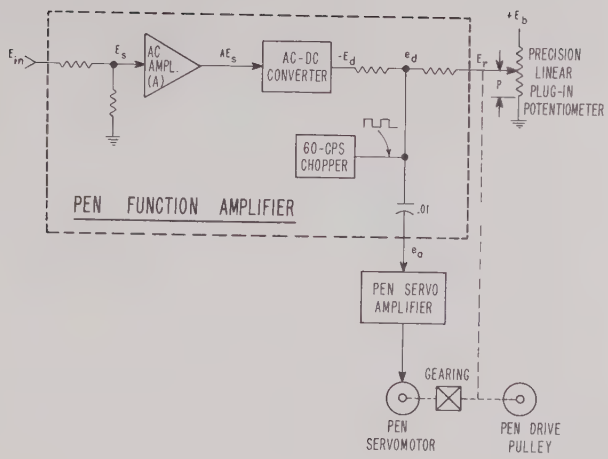
Since $\frac{A}{E_r}$ is constant,

$$P = \log E_s + K \, . \tag{20}$$

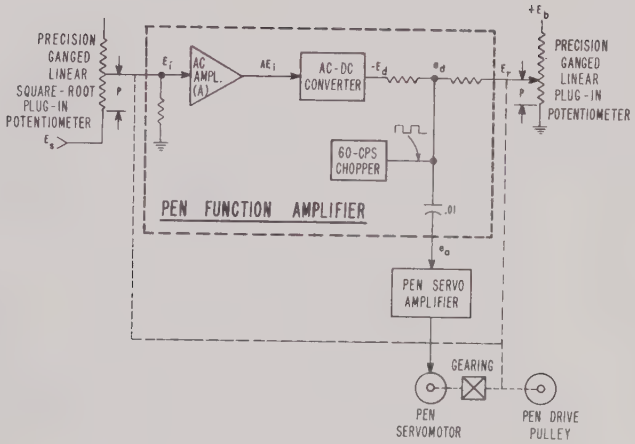
3.3.2 Signal Monitor Meter Circuit

The ac signal from the preamplifier enters on pin 1 of A2J1. Coarse attenuation is provided by A2S3 and the voltage divider consisting of A2R72, -R73, -R74, -R75, and -R76. Fine control is accomplished by METER GAIN control A2R75. The signal is amplified by A2V6 and A2V7 and rectified by A2CR11 and A2CR12. The current through A2CR12 is proportional to the input signal and is measured by the meter (A2M1).

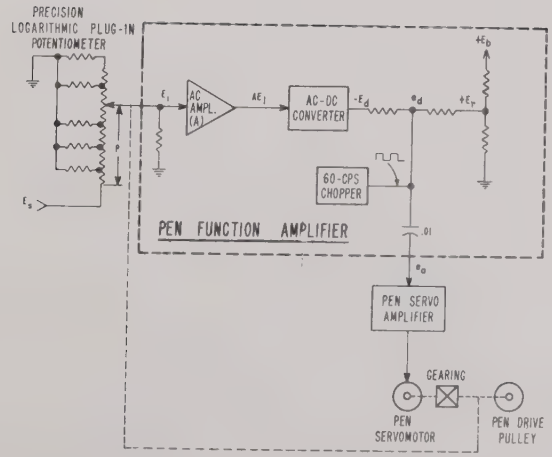
The meter is also used to measure bolometer current in those systems with crystal-bolometer amplifiers. The bolometer current signal enters on pins 13 and 14 of A2J1.



A--Linear Function



B--Square-Root Function



C--Logarithmic Function

Fig. 3.2. Simplified Diagrams of Pen Function Circuits

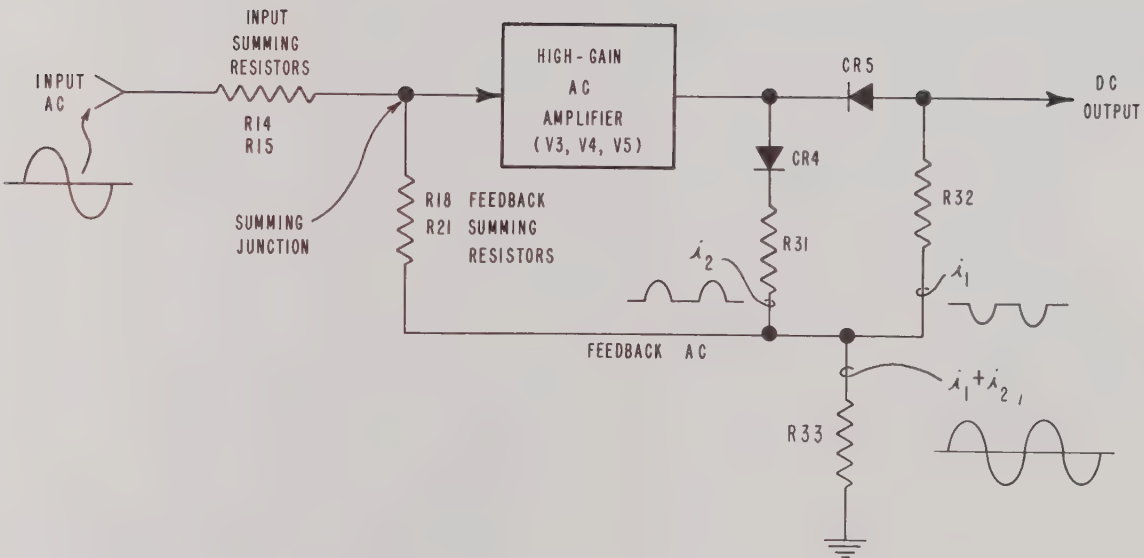


Fig. 3.3. Simplified Diagram of AC to DC Converter

3.3.3 AC to DC Converter

This circuit utilizes electronic feedback to accurately convert the ac signal into a dc form. Fig. 3.3 is a simplified diagram of the ac to dc converter. Tube A2V5 drives two diodes (A2CR4 and A2CR5) which rectify the ac signal. During the positive half-cycle swing of tube A2V5, A2CR4 conducts and a positive current i_1 flows through A2R31 and A2R33. During the negative half-cycle, A2CR5 conducts and a negative current i_2 flows through A2R32 and A2R33. Since A2R33 is common to both the negative and positive currents (i_1 and i_2), an ac signal is developed across it. This ac signal is fed back to the summing junction by A2R21 and A2R18 and is 180° out of phase with the input ac signal. The difference between the feedback signal and the input signal is amplified and rectified. Since the cascaded gain of A2V3, A2V4, and A2V5 is extremely high, the waveform through A2R33 is forced to follow the input signal waveform. The half-loop negative voltage across A2R32 is exactly proportional to the ac signal.

A filtering network (A2R34, A2R35, A2C16, and A2C17) and a summing network (A2R50 and A2R54) filters and sums the dc voltage with the wiper voltage of the linear plug-in follow-up potentiometer, located in the pen servo system, in linear or square-root operation (refer to paragraph 3.3.7 for logarithmic function).

If the two voltages do not correspond, the dc error voltage at the junction of A2R50 and A2R54 is chopped by transistor chopper A2Q3 into a 60-cps* square-wave voltage. The 60-cps* error voltage leaves the pen function amplifier on pin 7 of A2J1.

The 60-cps* error voltage serves to drive the recorder pen and follow-up potentiometer to a null position.

3.3.4 DC to AC Chopper

A 6.3v, 60-cps* reference signal is applied to the input base of an emitter-coupled binary consisting of transistors A2Q1 and A2Q2. Potentiometer A2R57 provides phase control of the reference signal to permit the phase of the servo loop to be optimized for either 50-cps or 60-cps operation. The signal at the collector of A2Q2 is a 60-cps square wave which is coupled to the base of the transistor chopper (A2Q3).

As the base of A2Q3 is driven positive by the 60-cps square wave, A2Q3 saturates, and its emitter is driven to ground potential. When the base goes negative, the emitter

*50-cps signal if operating from an ac line frequency of 50 cps.

returns to the summing junction potential. By this process, the dc error voltage is converted into a half-wave ac signal. Diodes A2CR9 and A2CR10 prevent damage to A2Q3 by the accidental application of extreme voltages from the summing junction. To minimize the high-frequency transient coupled through the chopper base-to-emitter capacitance, an opposing transient obtained from the collector of A2Q1 is coupled to the emitter of A2Q3 through variable capacitor A2C27.

3.3.5 Linear Operation

When in the linear mode of operation, the ac signal from the preamplifier enters on pin 2 of A2J1. It is divided by A2R2 and A2R3, amplified by A2V1 and A2V2, and applied to the Full Scale potentiometer (A2R13). The signal at the wiper of A2R13 is applied to input summing resistors A2R14 and A2R15 of the ac to dc converter circuit (see Figs. 7.6 thru 7.10 and paragraph 3.3.3).

The wiper of the PEN ZERO adjust potentiometer applies a small negative voltage to the bottom of the linear plug-in potentiometer to permit limited adjustment of the pen position at zero on the chart scale for linear and square-root operation.

3.3.6 Square-Root Operation

When in the square-root mode of operation, the signal enters the pen function amplifier on pin 2 of A2J1 and is applied across A2R1. It is then coupled to the ac section of the square-root plug-in potentiometer through pin 1 of A2J2. The wiper voltage from the ac section returns on pin 7 of A2J2 and enters the grid of tube A2V1. Resistor A2R6 loads the wiper of the ac section of the potentiometer. The signal is amplified by tubes A2V1 and A2V2, and is rectified by the ac to dc converter (A2V3, -V4, -V5, and associated components). The converter output is summed with the output of the linear potentiometer to provide a bidirectional error signal.

During square-root operation, diode A2CR8 and resistor A2R90 are switched in to provide proper pen damping. Diode A2CR8 conducts for large negative error signals and causes A2R53 to load the summing junction. This prevents an undesirably large overshoot of the pen for signals driving the pen upscale. The pen position at zero on the chart scale for square-root operation is determined by the PEN ZERO adjustment as in the linear mode of operation.

3.3.7 Logarithmic Operation

When operating in the logarithmic mode, the ac signal enters the pen function amplifier on pin 1 of A2J1 and is connected through A2S1 to pin 9 of A2J2 from where it is

connected to the logarithmic plug-in potentiometer. The wiper voltage of the logarithmic potentiometer is returned on pin 15 of A2J2 and is coupled to the grid of tube A2V1. The signal is amplified and rectified by tubes A2V1 through A2V5. Since the ac signal is at a very low level (0.8 mv) and always returns to this constant level with the pen nulled, the signal processing is slightly different from the linear and square-root functions (see paragraphs 3.3.5 and 3.3.6).

In the logarithmic mode of operation, feedback resistor A2R33 is shunted by A2R36 thereby increasing the closed-loop gain of A2V3, A2V4, and A2V5. The filtered and rectified output of the ac to dc converter is summed with a reference voltage supplied through A2R43; the resultant signal appears at the junction of A2R35 and A2R43. The composite error voltage is applied to transistor chopper A2Q3 through resistors A2R47 and A2R49, and Log Loop Gain control A2R51. This control determines the pen servo gain when in the logarithmic mode of operation.

Because of the logarithmic pen functions, the slope of the error signal when the pen travels upscale is much larger than the slope of the error signal when the pen travels downscale. To compensate for this difference, the upscale negative signals are shunted by diode A2CR6 and the Log Damping potentiometer (A2R46).

3.4 Power Supply and Servo Amplifier

A schematic diagram of the power supply and servo amplifier unit is located at the rear of this manual (Fig. 7.3). This unit contains the following circuits:

(a) A +13-volt, 2a power supply which furnishes +13 volts (regulated) to the tube filaments and the bolometer bias supply.

(b) A +250-volt, 60-ma power supply which furnishes a highly regulated 250 volts for the tube plate voltages and for potentiometer reference voltages.

(c) A −28-volt, 3a power supply which supplies 28 volts (regulated) for the pen and chart servo amplifiers.

(d) A pen servo amplifier which receives a low-level 60-cps* ac error signal from the pen function amplifier and amplifies it to drive the pen servomotor.

(e) A chart servo amplifier which receives a 60-cps* ac error signal from the chart synchros and amplifies it to drive the chart servomotor.

*50-cps signal if operating from an ac line frequency of 50 cps.

(f) A pen noise-compression circuit (located in the 60-cps* pen servo amplifier) which provides compression of the recording pen noise response. Pen dynamic errors are also increased, requiring recording at a reduced rate.

3.4.1 +13-Volt Power Supply

Power transformer A4T1 furnishes an output of 20 volts at 2.5 amperes to a bridge rectifier consisting of A4CR34, -CR35, -CR36, and -CR37. The 13-volt regulator consists of dc-coupled amplifiers A4Q23 through A4Q29, reference diode A4CR40, and series regulator stage A4Q25. The output voltage is adjustable by means of potentiometer A4R99. The typical peak-to-peak ripple at the power supply output terminals is less than 3 millivolts.

3.4.2 +250-Volt Power Supply

Power transformer A4T1 furnishes an output of 6.3 volts at 1.5 amperes for the series regulator tube (A4V1) filaments. Transformer A4T1 also furnishes an output of 157 volts at 250 ma to the doubler-rectifier (A4CR19, A4CR20, A4C22, and A4C23) for the 250-volt power supply. This power supply, capable of furnishing a total output current of 60 ma, furnishes the tube plate voltages and the balance potentiometer reference voltages. The regulator circuit for the 250-volt power supply consists of transistor amplifier stages A4Q11 through A4Q14, voltage-reference tubes A4V2 and A4V3, and series regulator A4V1. The typical peak-to-peak ripple at the power supply output terminals is less than 1 millivolt.

3.4.3 −28-Volt Power Supply

Power transformer A4T1 furnishes an output of 33 volts at 3 amperes to a bridge rectifier consisting of A4CR29, -CR30, -CR31, and -CR32. The −28-volt regulator consists of dc-coupled amplifiers A4Q21 and A4Q22, reference diode A4CR33, and series regulator stages A4Q20. The output voltage is adjustable by means of potentiometer A4R84. The typical peak-to-peak ripple at the power supply output terminals is less than 0.1 volt.

3.4.4 Pen Servo Amplifier

The pen ac error signal enters on pin F of A4J3 and is applied to the base of emitter follower A4Q3. Resistor A4R20 and capacitor A4C7 provide RC feedback to increase

*50-cps signal if operating from an ac line frequency of 50 cps.

the input impedance to about 470,000 ohms. This signal is applied to the base of A4Q1 and amplified by A4Q1 and A4Q2. Resistor A4R4 provides negative feedback to the amplifier pair for ac and dc stability. From the collector of A4Q2, the signal leaves on pin T of A4J1 (NOISE COMPRESSION switch in the off position) and returns on pin S of A4J1 from the wiper of the Pen Gain control (R14) located on the recorder head. When noise compression is selected (NOISE COMPRESSION switch ON), the signal is taken from pin U of A4J1 and returns on pin S of A4J1 as before.

The signal is then further amplified by A4Q4, filtered by A4R28, A4R29, and A4C10 and amplified again by A4Q5 and A4Q6. The output of A4Q6 is fed to the base of a push-pull, driver amplifier (A4Q7 and A4Q8). Capacitor A4C14 couples the signal from the emitter of A4Q7 to the emitter of A4Q8, thus driving the two transistors in an inverted fashion. Transistors A4Q9 and A4Q10 are the power output amplifiers, also connected in push-pull and driving the center-tapped motor winding directly. Capacitors A4C15 and A4C16 provide additional signal filtering.

Tachometer voltage for damping of the servo system enters on pin R of A4J1 and is summed at the base of A4Q5.

Resistor A4R31 and capacitor A4C12 provide the proper amount of phase shift. The reference windings of the pen servomotor are energized from the ac line.

3.4.5 Noise-Compression Circuit

To obtain additional noise rejection when signal sensitivity is at a premium, a noise-compression circuit may be switched in. This circuit provides shaping of the error signal and automatically reduces the pen servo gain when large random noise pulses enter the circuit.

A simplified schematic, Fig. 3.4, illustrates the basic noise-compression circuit. It consists of three basic parts designated circuit A, circuit B, and circuit C. Circuits A and B together produce an error-shaping response as shown. For small error signals, circuit A passes the signal and the servo system performs normally. As the error increases, the servo gain is reduced as circuit A ceases conduction. For large errors, the gain is restored when circuit B starts conduction such that high slewing speeds are maintained.

Circuit C provides a low-impedance path to ground for rapidly changing or noise errors and reduces the gain significantly, even when circuit B is conducting. Large noise spikes are greatly attenuated by the low-impedance path to ground of circuit C. If the error should remain during slewing, for example, circuit C is automatically disabled, and the pen gain is restored.

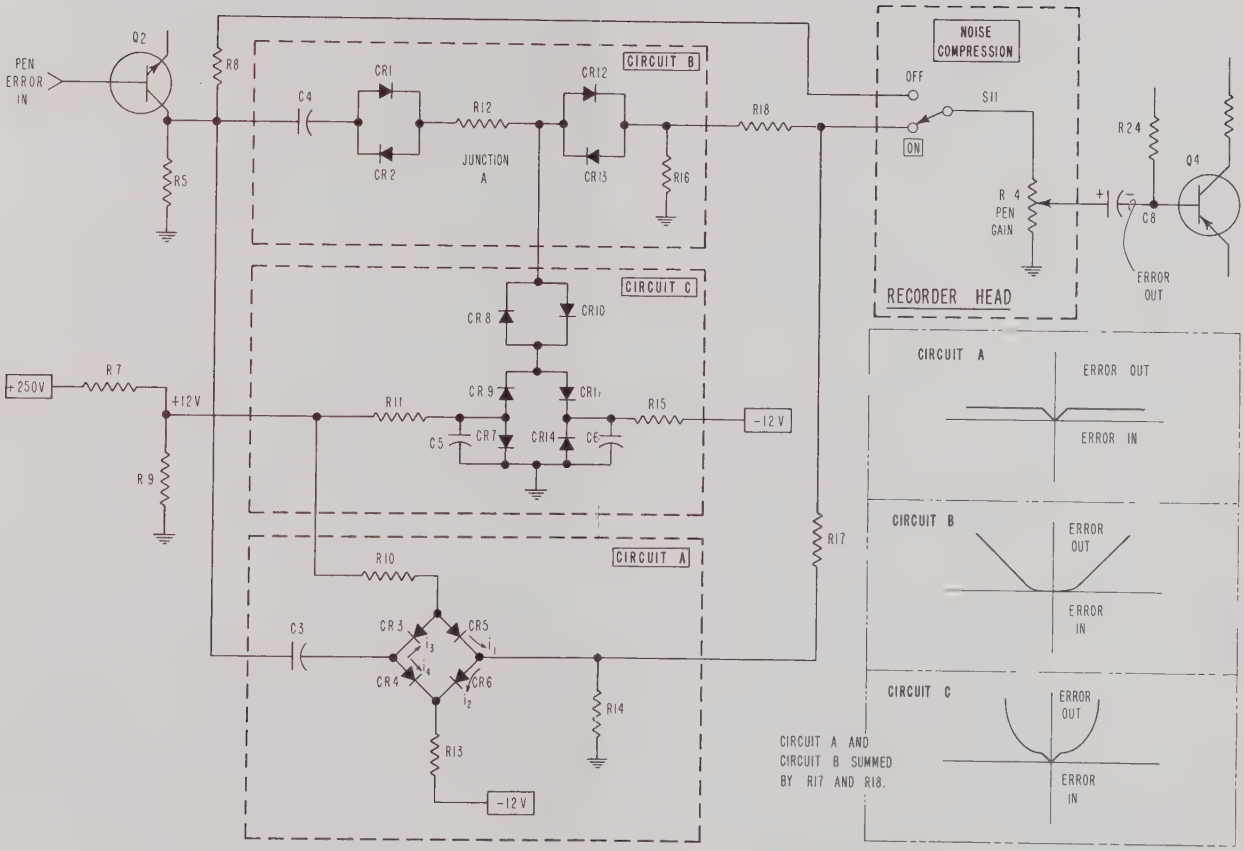


Fig. 3.4 Simplified Diagram of Noise Compression Circuit

applied to Chart Gain control A3R6 (located on the recorder head) and enters on pin M of A4J1. The 60-cps* chart tachometer signal is applied to Chart Tach control A3R15 (located on the recorder head) and enters on pin L of A4J1. These two voltages are summed by a resistive network (A4R66 and A4R67) and applied to the base of transistor A4Q15. Resistor A4R67 and capacitor A4C28 also provide the proper amount of phase shift. Diodes A4CR25 and A4CR26 are used to clip large input signals to prevent saturation of the servo amplifiers.

The output of A4Q15 is fed to the base of a push-pull driver amplifier (A4Q16 and A4Q17). Capacitor A4C33 couples the signal from the emitter of A4Q16 to the emitter of A4Q17, thus driving the two transistors in an inverted fashion.

Transistors A4Q18 and A4Q19, power output amplifiers also connected in push-pull, drive the center-tapped motor winding directly. Capacitors A4C34 and A4C35 provide additional signal filtering. The servomotor reference windings and the synchro transmitter rotor windings are energized from the ac line.

3.5 Recorder Head

A schematic diagram of the recorder head is located at the rear of this manual (Fig. 7.4). This unit contains the front-panel controls for the pen and chart system, a differential control transmitter, control transformers, the plug-in follow-up potentiometer, and the associated gearing necessary for graphical rectangular coordinate plotting.

3.5.1 Control Circuits

On-off switching of the pen drive motor (A3B5) and the chart drive motor (A3B7) is provided by A3S12 and A3S10, respectively. (A remote switch for on-off control of the pen motor may be connected to A3J5. A remote switch for on-off control of the chart motor may be connected to pins A and B of A3J7. For remote operation, switches A3S10 and A3S12 must be OFF. See paragraph 2.10.)

Any one of three synchro inputs may be selected by the CHART DRIVE switch (A3S1). Chart-scale expansion is provided by the CHART MOTION (DEGREES/CYCLE) switch (A3S2), and chart direction is reversed with the CHART MOTION (FORWARD-REVERSE) switch (A3S3).

The PEN (LIFT-WRITE) switch (A3S9) energizes a solenoid (A3K3) when in the WRITE position to allow the pen to contact the chart surface. When this switch is in the LIFT

*50-cps signal if operating from an ac line frequency of 50 cps.

position, a remote switch connected to A3J6 will permit remote control of the pen writing (see paragraph 2.10).

The CHART MANUAL CONTROL (FORWARD-REVERSE) switch (A3S4) permits either forward or reverse chart drive at a constant speed. This speed is determined by adjustment of the Forward Speed (A3R3) and Reverse Speed (A3R2) potentiometers located on the service panel at the top of the recorder head. A 12.6v rms voltage, center-tap grounded (from pins J and H of A3J4), is applied to the Forward Speed and Reverse Speed potentiometers as a constant chart error signal.

Depressing the CYCLE REVERSE button (A3S6) de-energizes pen-lift solenoid A3K3 and energizes cycle solenoid A3K2, which closes the cycle switch (A3S5) (see Fig. 4.3). The cycle switch applies a constant error voltage from the wiper of the Reverse Speed potentiometer (A3R2) to the input of the chart servo amplifier through the Chart Gain potentiometer (A3R6) and pin M of A3J4. The magnitude of this error voltage is set by the Reverse Speed potentiometer and provides chart rotation at the same speed as that obtained during operation of the CHART MANUAL CONTROL (FORWARD-REVERSE) switch (A3S4).

When the cycle solenoid is energized, it pulls a cam wheel against a friction drive wheel in the chart drive train. A chart-cycle cam, behind the cam wheel, operates the cam switch; the cam switch holds the cycle solenoid energized and the pen-lift solenoid de-energized after the CYCLE REVERSE pushbutton is released.

The solenoids remain in this state until the cycle cam completes one revolution. At this time, the cam switch opens and removes the voltage from the cycle solenoid and applies voltage to the pen-lift solenoid. When the cycle solenoid releases, the cycle switch reconnects the chart servo amplifier input to the servo system. When initiating the automatic cycle reverse, the CYCLE REVERSE switch must remain depressed until the cam switch closes. (Remote operation of the CYCLE REVERSE switch can be accomplished by connecting a normally open switch to pins A and C of connector A3J7, see paragraph 2.10.)

When the CYCLE ADVANCE button (A3S7) is depressed, it de-energizes the pen-lift solenoid and closes forward cycle relay A3K1. This relay switches the error voltage from the Reverse Speed potentiometer (A3R2) to the Forward Speed potentiometer (A3R3) and energizes the cycle solenoid which closes the cycle switch. The cycle switch applies a constant error voltage from the wiper of the Forward Speed potentiometer to the input of the chart servo amplifier through the Chart Gain potentiometer (A3R6) and pin M of connector A3J4. The magnitude of this error voltage is set by the Forward Speed potentiometer and provides chart rotation at the same speed as that

obtained during operation of the CHART MANUAL CONTROL (FORWARD-REVERSE) switch (A3S4).

The cycle solenoid pulls the cam wheel against the friction drive wheel as described above. As the wheel turns, the cam depresses the cam switch. The switch closes and holds the forward cycle relay closed, the cycle solenoid energized, and the pen lift solenoid de-energized.

When the cycle cam completes one revolution, the cam switch opens and removes voltage from the forward cycle relay and the cycle solenoid, and applies voltage to the pen lift solenoid. When the cycle solenoid is released, the cycle switch reconnects the input of the chart servo amplifier to the servo system. When initiating the automatic cycle advance, the CYCLE ADVANCE button must be held until the cam switch closes. (Remote operation of the CYCLE ADVANCE switch can be accomplished by connecting a normally open switch to pins A and E of connector A3J7, see paragraph 2.10.)

CHART ZERO adjustment is by a differential control transmitter (A3B1) connected in series with the external torque transmitters and the control transformers located in the recorder head (A3B2, A3B3, and A3B4*). With the CHART ZERO knob, the operator can orient the chart drive with respect to the positioner turntable. A calibrated readout permits the chart drive to be reset to any reference position.

3.5.2 Chart Drive Mechanical System

The chart roll is supported between two discs, one of which is spring-loaded (right) and the other keyed to accept a notch in the chart roll. The left disc is geared to the rewind motor which maintains constant tension on the chart paper. This motor will withstand continuous stalling without damage.

The chart is fed behind and over the sprocketed chart drive drum and under the chart hold-down slips. The chart drive drum is driven by the gear train located outside the left end-plate. This gear train consists of the chart servomotor pinion (see Fig. 3.5), which drives large gear and pinion "A" attached to the shaft of the 6:1 synchro control transformer. The pinion on gear "A" drives large gear "B" on the shaft of the 1:1

*A3B4 is supplied only with Option S36.

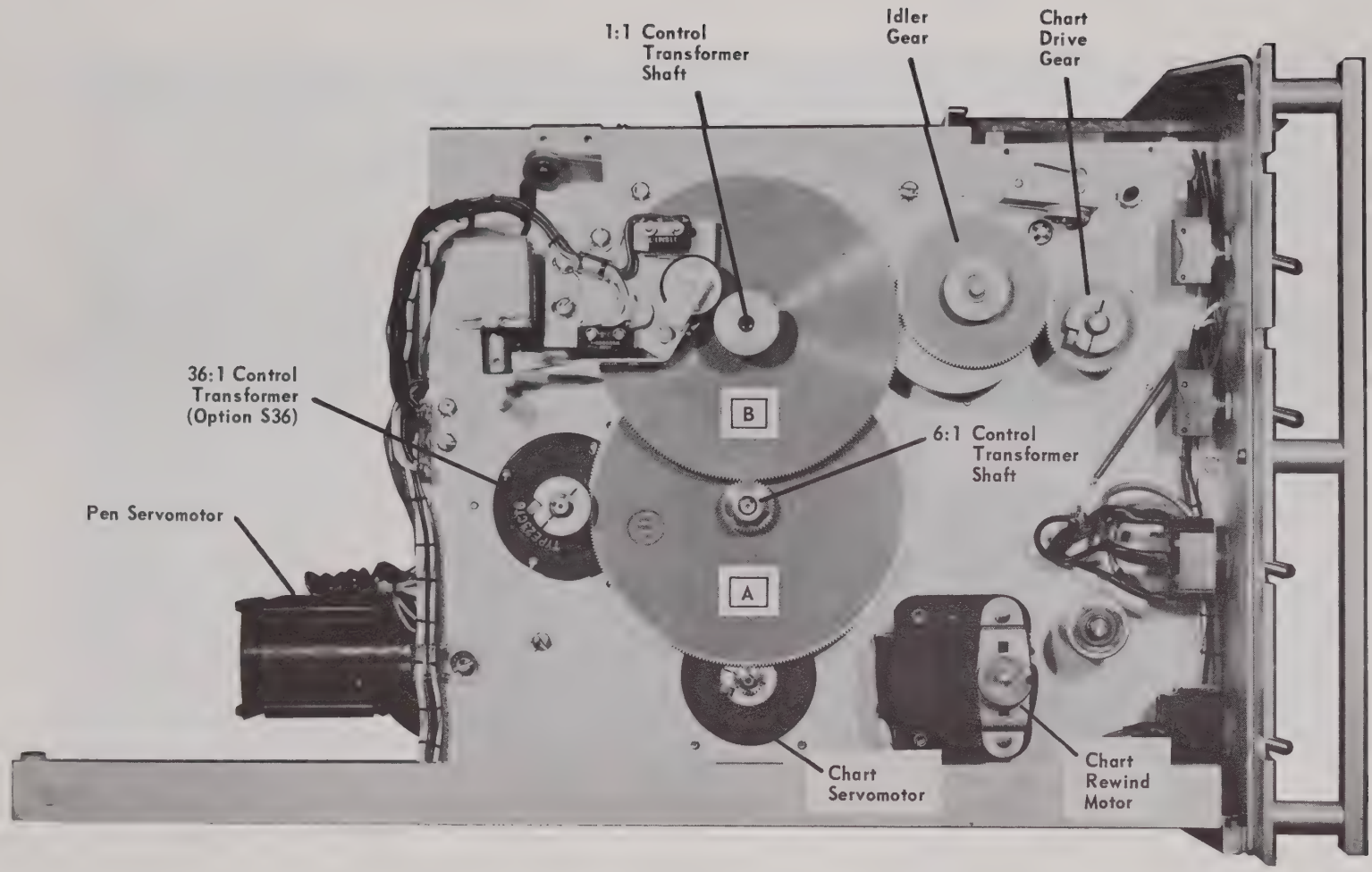


Fig. 3.5. Left Side of Recorder Head Showing Chart Drive System

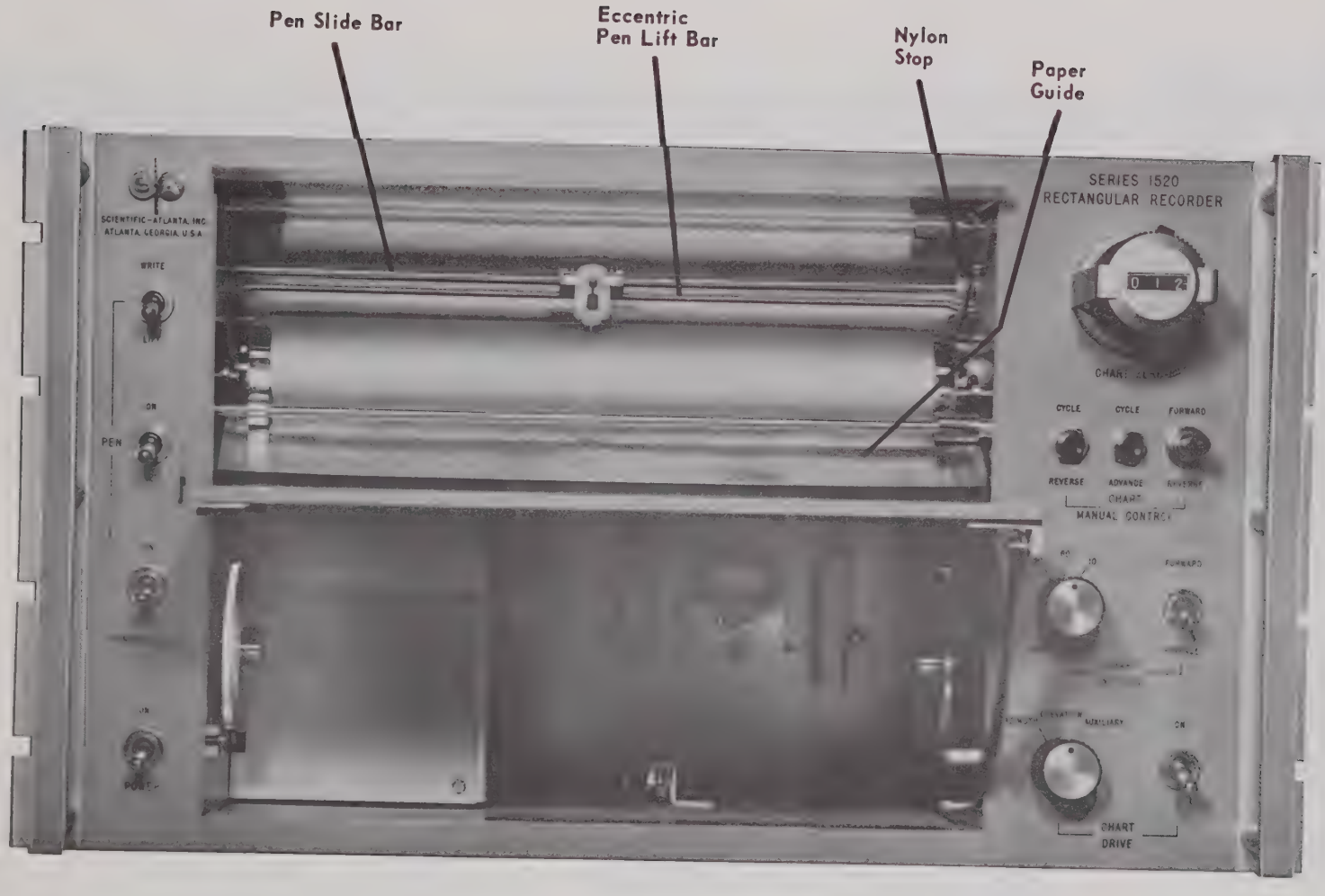


Fig. 3.6. Front View of Recorder Head With Chart Roll Removed

synchro control transformer which then drives the idler gear (models without Option C) and the chart drive gear.

3.5.3 Pen Drive Mechanical System

The pen servomotor (Fig. 3.5) drives the plug-in follow-up potentiometer and the pen cable drum through a precision gear and pinion assembly. The rotary motion of the pen cable drum is converted to linear motion across the chart writing surface by the pen drive cable. Mechanical stops limit the rotation of the pen cable drum and thus limit the cable travel to a distance slightly greater than the length of the chart scale.

The pen is switched between the "lift" and "write" positions by an eccentric pen lift bar (see Fig. 3.6). The pen lift bar is moved to a position clear of the pen holder when it is rotated by the pen lift solenoid; the weight of the pen and pen holder causes the pen to drop and contact the chart surface. When the solenoid is de-energized, a pen lift spring (Fig. 4.4) rotates the pen lift bar to lift and hold the pen in the "lift" position.

3.5.4 Option C--Chart Compression

This option provides two recorder chart-cycle lengths; a 20-inch chart-cycle length for standard recordings, or an 8-inch chart-cycle length to provide page-size recordings.

The shift from one chart-cycle length to the other is accomplished by a gear train (see Fig. 2.4) encased in a swinging sector plate mounted on the left end plate of the recorder head. Knurled screws are provided to hold the swinging sector plate in either of two positions.

Option C can be installed at the factory, or can be installed in the field by a mechanical technician. Details are given in paragraph 5.9.

3.5.5 Option S36--36:1 Control Transformer

This option contains a third synchro control transformer which is driven from large gear "A" (see Fig. 3.5). The control transformer (A3B4) permits a 360-degree chart cycle with a 36:1 synchro transmitter in the positioner as the input.

Option S36 can be installed at the factory, or can be installed in the field by a mechanical technician (see paragraph 5.10).

CHAPTER 4
ADJUSTMENTS

The adjustments described in this chapter were made at the factory before the recorder was shipped. Readjustment should be required only to correct for normal component aging and possibly after parts replacement. Before performing an adjustment, read the entire procedure carefully. No damage to the instrument will result, but a certain amount of frustation may be encountered.

If it appears necessary to check the linearity of the pen system, follow the procedure given in paragraph 5.6.

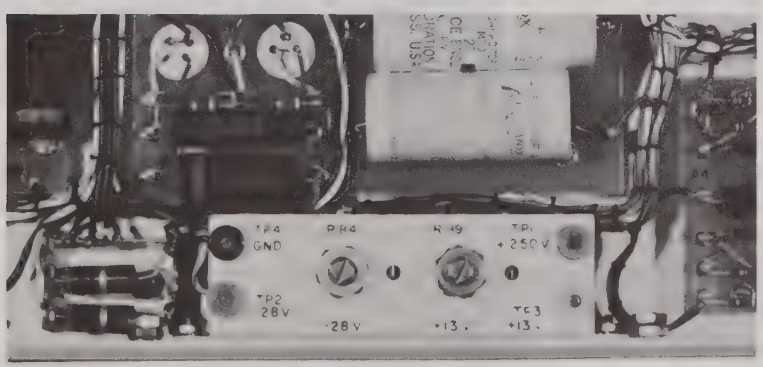
4.1 Power Supplies

The +13-volt and −28-volt power supplies are adjustable; the +250-volt supply is fixed.

To adjust the output level of the +13-volt dc filament supply, measure the voltage at TP3 and TP4 located on the small panel directly above the fan in the servo amplifier and power supply (see Fig. 4.1). Adjust (A4)R99 for 13±0.5 volts. The recorder will perform satisfactorily at any dc filament voltage level within this range.

Measure the voltage between TP2 and TP4 and adjust (A4)R84 for a meter reading of −28±2 volts.

Lock both controls.



P1359

Fig. 4.1. Power Supply Adjustment Panel

Check the +250-volt supply at TP1 and TP4. This supply should regulate within ±2%. If the supply does not regulate within this range, a circuit malfunction is indicated. Refer to paragraph 5.1.1 for maintenance information.

If all voltages are normal, slide the chassis back into the cabinet and secure it.

4.2 Chart Servo System

The Gain and Tach controls of the chart amplifier should be adjusted for maximum servo-loop tightness and for critical damping. A measure of loop tightness is the ability of the chart to return to the same null after being displaced from the null in either direction. Damping is measured by the ability of the chart to abruptly cease motion. Critical damping is obtained when the chart stops upon a servo command without noticeable overshoot or undershoot of the null point.

To permit adjustment of the Chart Gain and Tach controls, slide the recorder head out approximately six inches (see Fig. 4.2). Connect the chart system to suitable synchros and place the DEGREES/CYCLE switch in the 10° position. Turn both the Chart Gain and Tach controls fully counter-clockwise, then turn the Chart Tach control approximately 1/4 turn clockwise. With the CHART DRIVE switch ON, advance the Chart Gain control clockwise until the chart system is nulled. (Use the CHART ZERO control to align the pen with one of the angle lines on the chart.) The Chart Gain control should be set to provide the minimum value of gain which causes the pen to return to the reference line after the chart is forcibly displaced either side of the null. Displacement of the chart from null can be accomplished by manually rotating the chart forward or backward with the fingers or by rotating one of the chart drive gears located on the left side of the recorder head assembly.

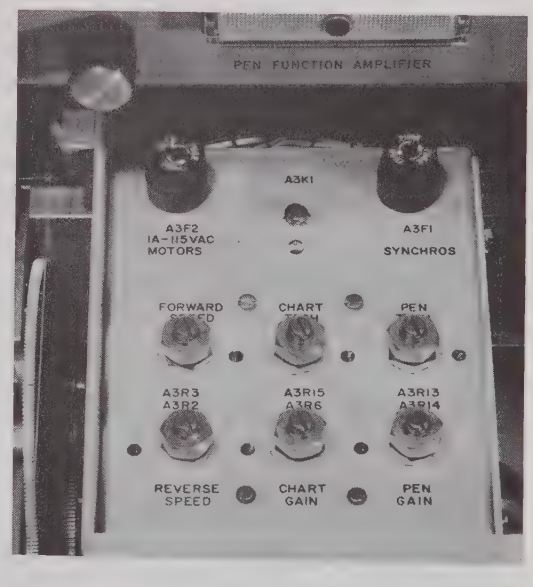


Fig. 4.2. Chart and Pen System Adjustments

The Chart Tach control may now be set for critical damping. A step function should be applied to the chart drive system by momentarily operating the CHART MOTION (FORWARD-REVERSE) switch. When applying this step function, observe chart overshoot or undershoot as the chart approaches the null. The Chart Tach control should be adjusted such that the chart approaches the null point at a steady rate of speed and stops without overshooting or undershooting. Undershoot is indicated by a noticeable reduction of chart speed as the null position is approached.

4.3 Pen Servo System

4.3.1 Preliminary Adjustments

The following adjustment points are located in the pen function amplifier.

(a) Connect an oscilloscope to the emitter of A2Q3.

(b) Set the Chopper Sym. control (A2R61) for a symmetrical square wave.

(c) Adjust trimmer capacitor A2C27 (located near A2Q3) for symmetrical spikes with the recorder pen nulled.

The following two steps should be followed with Models 1555-2, 1555-3, and 1555-5 Pen Function Amplifiers; use logarithmic function.

(d) Set the CBA output to 10 volts rms (high signal output).

(e) Set the Full Scale adjustment (A2R13) for full-scale pen deflection.

The following five steps should be followed with Models 1555-1 and 1555-4 Pen Function Amplifiers; use linear function.

(f) Set the CBA GAIN and ATTENUATOR controls fully clockwise.

(g) Apply a signal (6-ohm impedance) at a level of 122 db below 1 volt rms to the BOLOMETER input connector.

(h) Set the Full Scale adjustment (A2R13) for full-scale pen deflection.

(i) Set the PFA for a LINEAR function and the CBA ATTENUATOR to OFF.

(j) Set the PEN ZERO adjustment on the PFA for zero on the chart.

4.3.2 Pen Servo Amplifier Adjustments

Two pen servo system adjustments are provided which determine the response of the recording pen. They are the Pen Gain and Pen Tach controls located on the service panel at the top of the recorder head (see Fig. 4.2).

Two additional controls are provided when a logarithmic pen function is used. They are the Damping and Log Loop Gain controls located at the rear of the pen function amplifier chassis.

When a pattern recorder is capable of being operated with more than one pen function, it is necessary to adjust the pen system controls for a particular function to provide proper adjustment for all functions. The following table shows the function to be used when adjusting the pen system of a multi-function recorder.

Recorder Model	Pen Function	Perform Adjustments Using Pen Function Below
1521	Linear	Linear
1522	Logarithmic	Logarithmic
1523	Linear-Logarithmic	Linear
1525	Linear-Square Root-Logarithmic	Linear

The procedure for pen servo amplifier adjustment is as follows:

(a) Determine the proper pen function from the table above and connect the recorder accordingly.

(b) Turn the Pen Gain and Tach controls fully counterclockwise. Turn the Pen Tach control 1/4 turn clockwise. For recorders with only a logarithmic function (1522, 1555-2), turn the Damping control fully counterclockwise and set the Log Loop Gain control about 30° off its counterclockwise stop.

(c) Set the ATTENUATOR on the preamplifier to 20 and apply a signal to the INPUT.

(d) Turn the Pen Gain control clockwise until the pen nulls. Set the signal level for a pen reading of approximately 90 on linear chart paper. The NOISE COMPRESSION switch must be off.

(e) Deflect the pen to either side of null with the finger to observe servo-loop tightness. Set the Pen Gain control to the minimum value of gain required for the pen to return to an accurate null.

*(f) Connect one channel of a dual-channel oscilloscope to the control winding (terminals 2 and 4) of the pen servomotor; connect the other

*Early versions of the pen function amplifier were not equipped with a Pen Phase potentiometer. If your PFA does not have a Pen Phase adjustment, skip step (f) and continue with step (g).

channel through two 47k, 1/2w resistors to the power line. The oscilloscope must be ungrounded. Adjust the Pen Phase potentiometer (in the pen function amplifier) for a 90-degree phase relationship (maximum loop tightness) between the control signal and the line voltage. Repeat step (e).

(g) Switch the ATTENUATOR on the preamplifier between the 20 db and 30 db positions to introduce pen steps. Set the Pen Tach control to allow a pen overshoot of approximately 1/8 inch for a step of the pen. (For logarithmic function, the overshoot will be greater on the upscale pen step.)

The following steps are applicable only to recorders with a logarithmic function.

(h) Install a logarithmic potentiometer (paragraph 2.4) and switch to the LOGARITHMIC pen function.

(i) Deflect the pen to either side of null with the finger to observe loop tightness, and switch the ATTENUATOR on the preamplifier between the 20 db and 30 db positions. Set the Log Loop Gain control to give an accurate null and a pen overshoot of approximately 1/8 inch on a downscale pen step.

(j) Switch the ATTENUATOR on the preamplifier between the 20 db and 30 db positions and set the Damping control to give a pen overshoot of 1/8 inch on an upscale pen step.

4.4 Mechanical

4.4.1 Chart Hold-Down Clips Adjustment

The chart is held in position at each end of the chart drive cylinder by a chart hold-down clip which is curved and slotted to fit over the sprocket and contact the paper on both sides of the sprocket. These two hold-down clips are independently spring-loaded to provide positive paper contact at both ends of the chart drive cylinder.

Spring tension on the left hold-down clip is provided by a spring and collar (located below the PEN LIFT-WRITE switch) which tends to rotate the support bar. Spring tension on the right hold-down clip is provided by a collar and spring attached to the clip which tends to rotate it (Fig. 4.4).

The adjustment of the left hold-down clip may be altered by loosening the set screw

which locks the clip to the support bar. The clip should be positioned so that it will lift approximately 1/16 inch before the right clip is engaged, and should be centered laterally over the sprocket pins on the chart drum. Care should be taken in adjustment to maintain the even center action of the spring and collar fastened to the support bar.

To adjust the right hold-down clip, loosen the set screws which lock the collar to the hold-down clip and slide the clip laterally to center the clip over the right chart drum pins.

Care should be taken to maintain the even center action of the spring.

Both hold-down clips should be adjusted so that they do not touch the paper guide (Fig. 3.6) when fully open.

4.4.2 Chart Cycle Mechanism Adjustment

The following adjustments should be maintained for proper operation (refer to Fig. 4.3):

(a) The clearance between the cam wheel and the friction drive wheel should be 0.007 to 0.012 inch when the cycle solenoid is released. This is adjusted by loosening screws "A" and tilting the mounting plate.

(b) The clearance between the advance arm and the actuator of the cycle switch should be 0 to 0.003 inch. Hold the armature of the cycle solenoid against the armature stop and rotate the stop for the proper clearance.

(c) The actuator roller on the cam switch should be aligned directly above the center of the cam wheel when the roller is in the cam notch. Loosen the cam switch mounting screws and move the switch for the proper alignment.

4.4.3 Pen Lift-Write Adjustment

The pen is lifted from and dropped on the chart writing surface by the action of an eccentric pen lift bar located behind and below the pen slide bar (see Fig. 3.6). When the pen lift solenoid (see Fig. 4.4) is energized, the pen lift bar clears the rear of the pen holder by approximately 1/32 inch when the pen is contacting the chart surface.

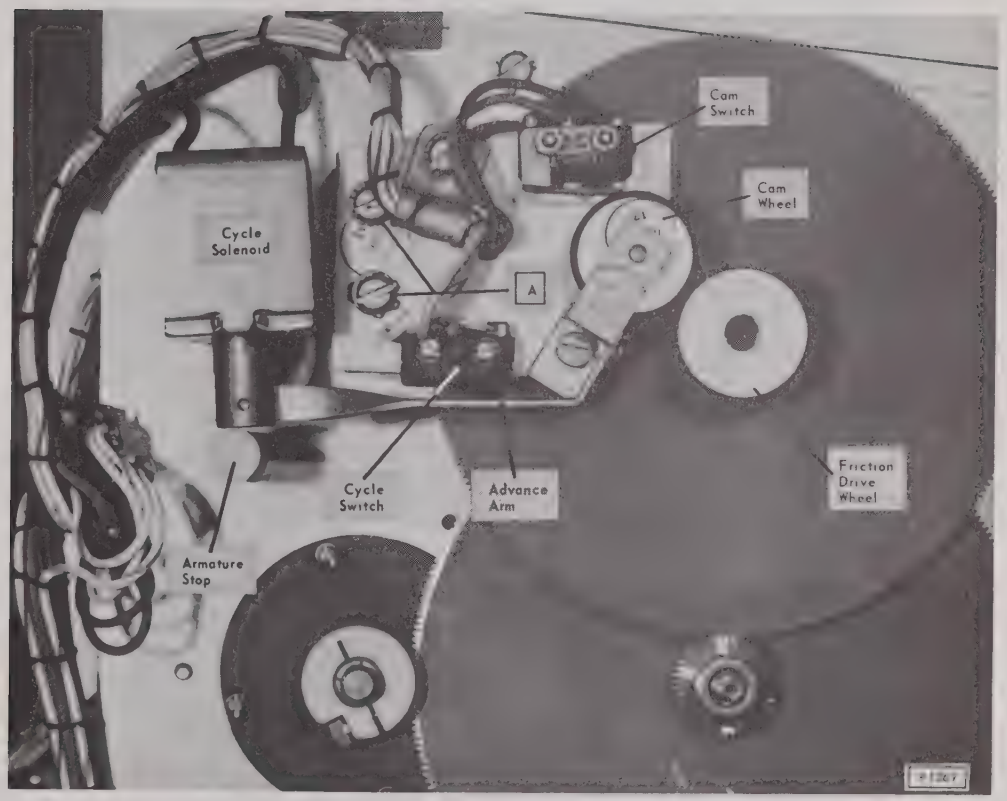


Fig. 4.3. Chart-Cycle Mechanism. This mechanism is located on the left side of the recorder head.

If adjustment of the eccentric pen lift bar is indicated, loosen the set screws in the pen lift cam and adjust the pen lift bar for 1/32-inch clearance at the rear of the pen holder with the pen lift solenoid energized.

4.4.4 Pen Drive Adjustment

There are no adjustments to be made to the pen mechanical system, other than that described in paragraph 4.4.3. An alignment procedure for the potentiometer drive mechanism is given in paragraph 5.4.

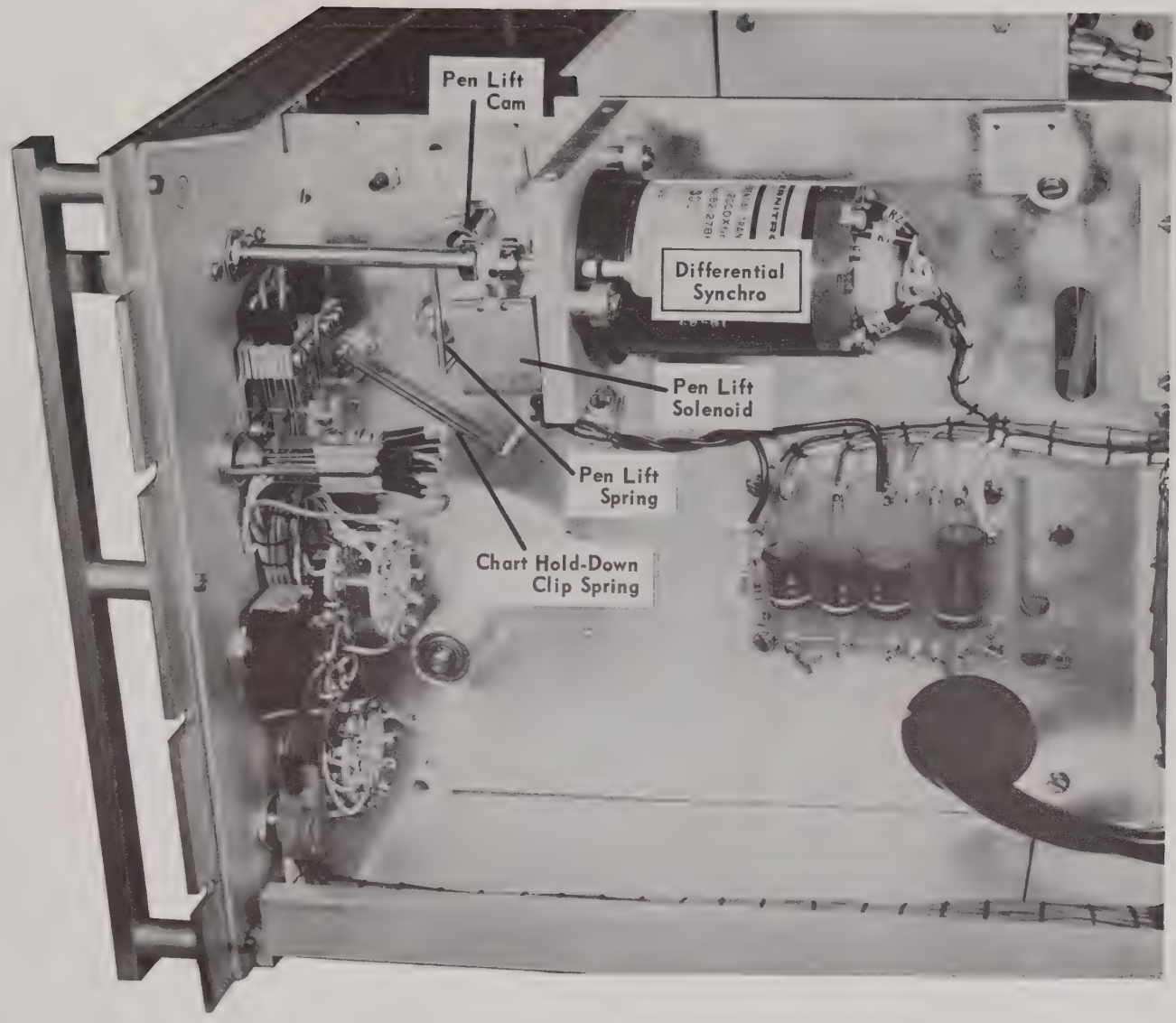


Fig. 4.4. Right Side of Recorder Head

CHAPTER 5
MAINTENANCE

5.1 General Procedures

In the event of faulty operation of any part of the recorder, a visual inspection of tubes, transistors, fuses, connectors, and other components should be completed first. Afterwards, standard troubleshooting procedures should be followed to isolate the trouble to a particular subunit, then to a single stage, and finally to the faulty part. To aid in this maintenance, schematic diagrams, static and dynamic voltage measurements, and waveforms are provided for each subunit as a guide for circuit tracing and for the testing of circuit performance.

The data furnished are complete for all options and models of the Series 1520 Pattern Recorders. When checking a model of the recorder which does not include a particular option, the excess information should be disregarded.

The following tables give typical values of dc and ac static voltages present at the terminals of the vacuum tube and transistor stages. All voltages are measured with respect to ground using a 20,000 ohms-per-volt dc voltmeter and a 1000 ohms-per-volt ac voltmeter, unless otherwise specified. The typical transistor base-to-emitter voltages are subject to considerable variation due to the variation of transistor parameters. All other voltages are subject to a variation of ±10%, unless otherwise specified.

The waveforms shown in the tables that follow are representative of those obtained from a normally operating unit. A Tektronix Type 513A Oscilloscope with a calibrated Type B Plug-In Unit was used; a low-capacity probe was used for those waveform measurements that involved high-frequency components.

To permit gain measurement, a signal may be applied to either the pen system or the chart system by manually displacing the recording pen or chart roll from a null with the servomotors off (PEN switch off and CHART DRIVE switch off). Only a slight displacement from null should be introduced to prevent amplifier saturation.

5.1.1 DC Power Supplies Troubleshooting

Although standard troubleshooting techniques may be employed in servicing the power supplies, interaction among circuits connected in a degenerative feedback loop may complicate isolation of the trouble. The nature of the device is such that if a malfunction makes any voltage change from normal, all voltages change from normal. Voltage

measurements should be made and then compared with the voltages shown in Table 5.1 as a group to establish the overall pattern of circuit conditions. Deductive reasoning should then allow cause to be distinguished from effect, to narrow the search to a particular group of components. These can then be tested individually.

	Transistor or Tube	Transistor or Tube Terminal							
		1 Base	2 Emitter	3 Collector	4	5	6	7	8
+250v Supply	A4V1	240	385	250	240	385	250	250	250
	-V2	165	83						
	-V3	83	0						
	-Q11	217	215	240					
	-Q12	217	215	238					
	-Q13	168	166	190					
	-Q14	168	166	192					
-28v Supply	-Q20	-28.2	-28	-35.5					
	-Q21	-28.5	-28.3	-35					
	-Q22	-17	-16.8	-28.5					
+13v Supply	-Q23	-6.3	-6.5	-1.2					
	-Q24	-1.2	-1	-7.2					
	-Q25	-1	-0.8	13.2					
	-Q26	11	10	13					
	-Q27	9.5	10	-1.2					
	-Q28	6.6	6.4	9.5					
	-Q29	6.6	6.4	11					

Table 5.1. DC Power Supply Voltages

5.2 Pen Servo System Measurements

5.2.1 Pen Function Amplifier

The general conditions for measurements are:

(a) Pen function amplifier connected to power supply and plug-in potentiometer

(b) Power supply connected to preamplifier

(c) Pen system nulled (except where noted)

(d) No signal applied to input.

Transistor or Tube Number	Transistor or Tube Terminal Designation						
	1 Base	2 Emitter	3 Collector	4	8	10	12
A2Q1	-2.5	-2.7	-4.1				
-Q2	-2.4	-2.7	-4.2				
-Q3	-0.15	0	0				
-V1		115		0	2.0	13	0
-V2		150		0	2.7	13	0
-V3		87		0	1.5	13	0
-V4		87		0	1.5	13	0
-V5		118		0	1.5	13	0
-V6		90		0	1.3	13	0
-V7		80		0	1.1	13	0

Table 5.2. Static Voltages in the Pen Function Amplifier

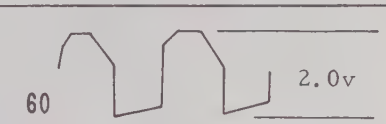
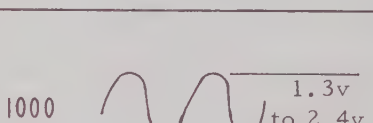
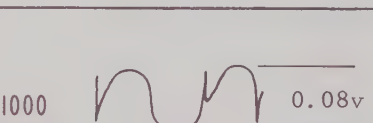
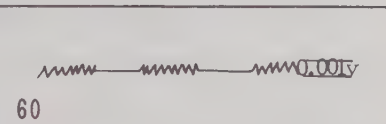
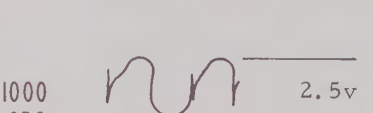
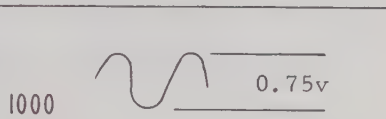
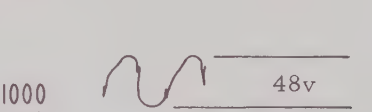
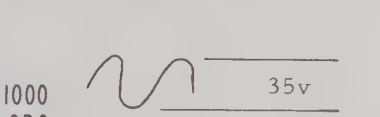
Gain Measured		Voltage Gain
From	To	
Base, A2Q1	Base, A2Q2	0.72
Base, A2Q2	Base, A2Q3	1.3
Emitter, A2Q3*	--	--
Pin 4, A2V1	Pin 4, A2V2	28
Pin 4, A2V2**	Pin 4, A2V3	1 and 2.3
Pin 4, A2V3***	Pin 4, A2V4	27
Pin 4, A2V4	Pin 4, A2V5	27
Pin 4, A2V5	Pin 2, A2V5	20
Pin 4, A2V6	Pin 4, A2V7	28
Pin 4, A2V7	Pin 2, A2V7	45

*This signal should vary from 0v to approximately 1.0v P-P by manually moving the pen to either side of the null. Phase will change by 180° when passing through the pen null.

**Pin 4 of A2V2 is set at 0.3v P-P by manually moving the pen from null. Gain of 1 for Linear and Square Root; gain of 2.3 for Logarithmic.

***Measurement made without diodes clipping.

Table 5.3. Voltage Gain in the Pen Function Amplifier

Test Point	Waveform	Test Point	Waveform
Pin 2 of A2V1		Collector of A2Q1	
Pin 2 of A2V2		Collector of A2Q2	
Pin 2 of A2V3		Emitter of A2Q3	
Pin 2 of A2V4		Pin 2* of A2V6	
Pin 2 of A2V5		Pin 2* of A2V7	
Base of A2Q1			

*Measurements made with meter set to 0 on meter scale.

Table 5.4. Waveforms in the Pen Function Amplifier
Pen nulled in all responses.

5.2.2 Pen Servo Amplifier

The following are general conditions for measurement: Power supply connected to pre-amplifier and pen function amplifier; pen function amplifier connected to the plug-in potentiometer; METER FUNCTION switch OFF; NOISE COMPRESSION switch off; PEN motor switch ON; CHART DRIVE switch ON; POWER switch ON. Both the pen system and the chart system should be in a nulled position.

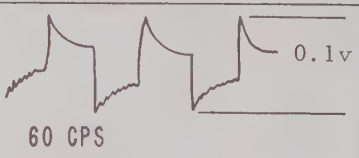
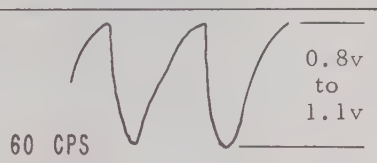
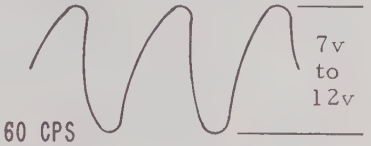
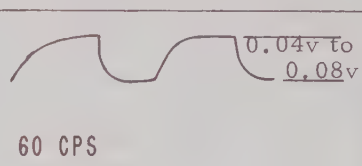
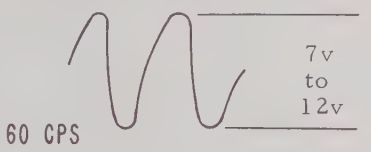
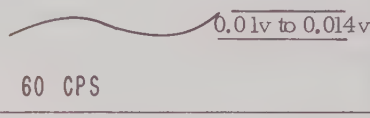
Transistor Number	Transistor Terminal		
	Base	Emitter	Collector
A4Q1	-7	-7.2	-11.2
-Q2	-11.2	-11.4	-6.8
-Q3	-5.8	-6.4	0
-Q4	-5.8	-6.0	-14.5
-Q5	-6.4	-6.6	-13.5
-Q6	-13.5	-14	-6.0
-Q7	-5.9	-5.8	-28
-Q8	-6.7	-6.6	-28
-Q9	-0.3	-0.1	-26.5
-Q10	-0.2	-0.1	-26.5

Table 5.5. DC Voltages in the Pen Servo Amplifier

Gain Measured		Voltage Gain
From	To	
Base, A4Q3	Base, A4Q1	0.33
Base, A4Q1	Base, A4Q2	3
Base, A4Q2	Base, A4Q4	0.14
Base, A4Q4	Base, A4Q5	1.8
Base, A4Q5	Base, A4Q6	0.5
Base, A4Q6	Collector, A4Q6	85
Collector, A4Q6	Collector, A4Q7	6
Collector, A4Q6	Collector, A4Q8	6
Collector, A4Q7	Base, A4Q9	0.13
Collector, A4Q8	Base, A4Q10	0.13
Base, A4Q9	Collector, A4Q9	0.23
Base, A4Q10	Collector, A4Q10	0.23

Conditions: Pen Gain control fully clockwise; Log Loop Gain control fully clockwise.

Table 5.6. Voltage Gain in the Pen Servo Amplifier

Test Point	Waveform	Test Point	Waveform
Base* of A4Q3		Collector of A4Q6	
Collector of A4Q1		Collector of A4Q7	
Collector of A4Q4		Collector of A4Q8	
Collector of A4Q5			

*Base of A4Q3 is set to 0.1v P-P by manually moving pen downscale from the null position. Measurements at A4Q1 through A4Q8 are made using this reference.
Conditions: Pen Gain control fully clockwise; Log Loop Gain control fully clockwise.

Table 5.7. Waveforms in the Pen Servo Amplifier
(All measurements made with respect to A4TP4)

5.3 Chart Servo System Measurements

The following are general conditions for measurement: Power supply connected to preamplifier and pen function amplifier; pen function amplifier connected to the plug-in potentiometer; METER FUNCTION switch OFF; NOISE COMPRESSION switch off; PEN motor switch ON; CHART DRIVE switch ON; POWER switch ON. Both the pen system and the chart system should be in a nulled position.

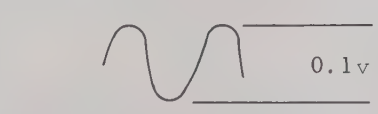
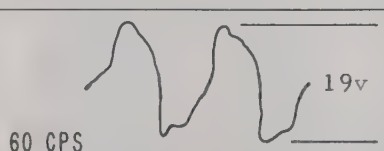
Transistor Number	Transistor Terminal		
	Base	Emitter	Collector
A4Q15	-6.4	-6.3	-22
-Q16	-6.5	-6.4	-28
-Q17	-6.3	-6.2	-28
-Q18	-0.3	-0.1	-26.5
-Q19	-0.3	-0.1	-26.5

Table 5.8. DC Voltages in the Chart Servo Amplifier

Gain Measured		Voltage Gain
From	To	
Base, A4Q15	Emitter, A4Q15	1
Emitter, A4Q15	Collector, A4Q16	40
Emitter, A4Q15	Collector, A4Q17	40
Collector, A4Q16	Base, A4Q18	0.17
Base, A4Q18	Collector, A4Q18	27
Collector, A4Q17	Base, A4Q19	0.17
Base, A4Q19	Collector, A4Q19	27

Conditions: Chart Gain control fully clockwise; Chart Tach control fully clockwise; CHART DRIVE switches in AZIMUTH and ON; CHART MOTION switches in FORWARD and 360.

Table 5.9. Voltage Gain in the Chart Servo Amplifier

Test Point	Waveform	Test Point	Waveform
Base* of A4Q15		Collector of A4Q19	
Collector of A4Q16		A4TP1	
Collector of A4Q17		A4TP2	
Collector of A4Q18		A4TP3	

*Base of A4Q15 is set to 0.1v P-P by manually moving chart from nulled position. Measurements at A4Q16 through A4Q19 are made using this reference.
Conditions: See Table 5.9.

Table 5.10. Waveforms in the Chart Servo Amplifier
(All measurements made with respect to A4TP4)

5.4 Potentiometer Drive Mechanism Alignment

If the positions of the pen cable drum and drive arm have been changed relative to each other, the potentiometer drive mechanism will have to be aligned.

After alignment, the phasing of each plug-in potentiometer that will be used with this recorder should be checked as described in paragraph 5.5.

5.4.1 Alignment Check

(a) Remove the pen cover and loosen the four screws that secure the pen holder to the pen cable.

(b) Rotate the pen cable drum (Fig. 5.1) fully clockwise (as viewed from front of recorder) against the mechanical stop.

(c) Align the potentiometer arm as in Fig. 2.1 and insert the potentiometer into its holder as shown in Fig. 5.1. The pin in the potentiometer arm should engage the drive arm as shown with a minimum of potentiometer-arm rotation.

(d) If the pin in the potentiometer arm engages the drive arm properly, skip to step 5.4.2(e). If not, proceed as follows.

5.4.2 Alignment Procedure

(a) Remove the potentiometer.

(b) Loosen the set screws in the drive arm (Fig. 5.2) and rotate the pen cable drum fully clockwise (as viewed from front of recorder) against the mechanical stop.

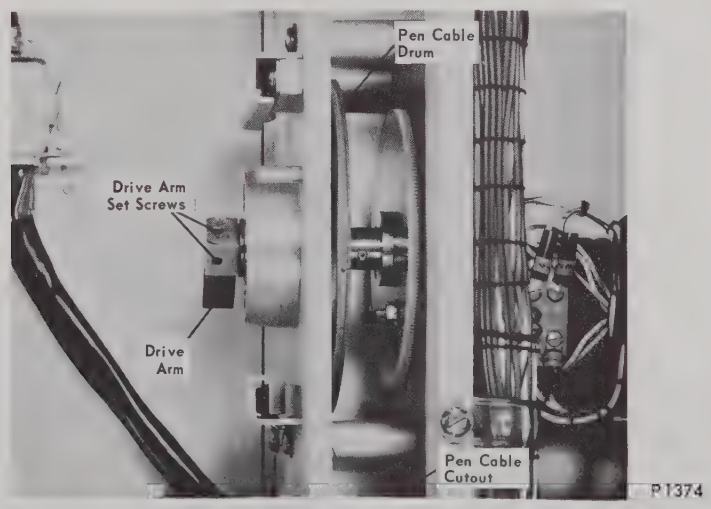


Fig. 5.2 Potentiometer Drive Mechanism

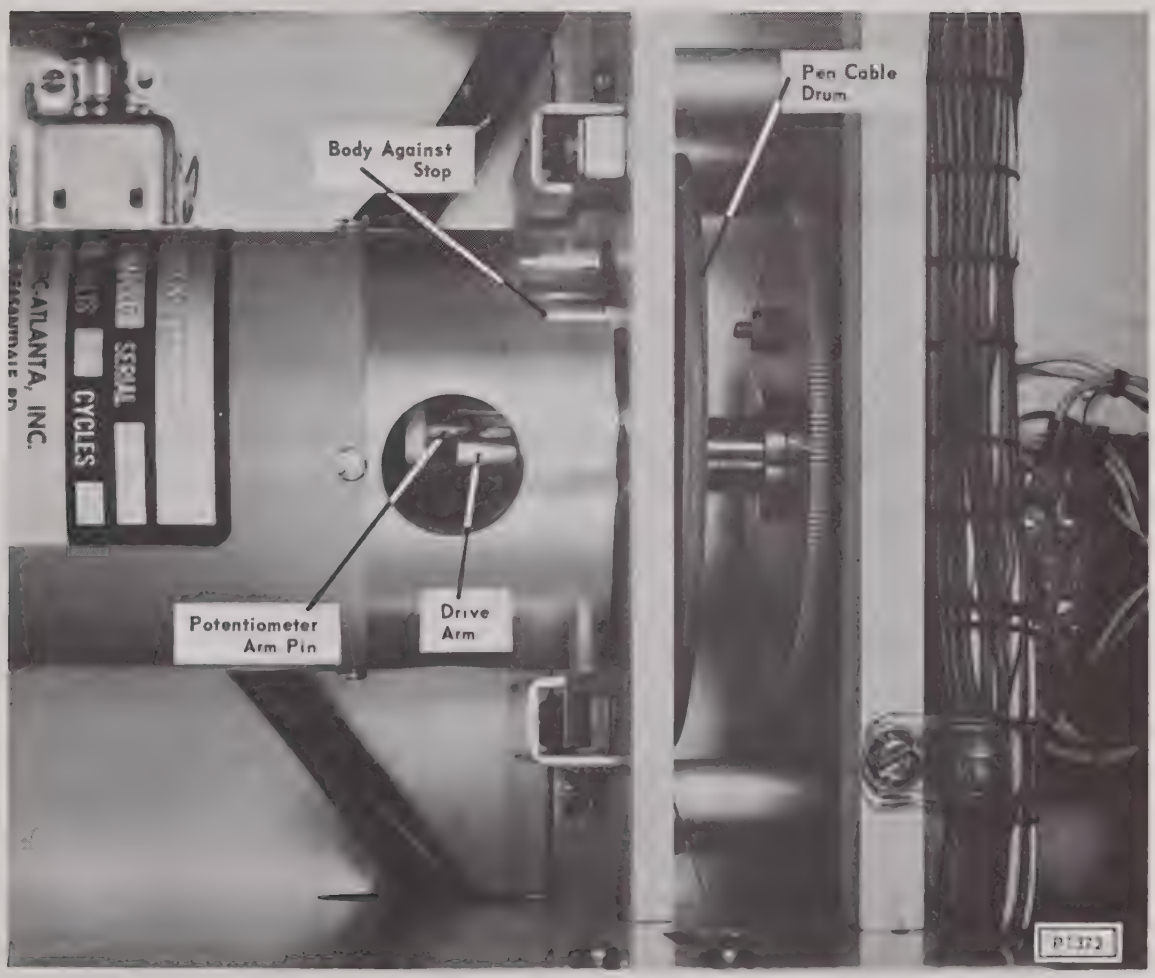


Fig. 5.1. Potentiometer Partially Installed

(c) Insert the potentiometer with its arm aligned as in Fig. 2.1 partially into its holder. Hold the potentiometer arm steady, the pen cable drum against the stop, and rotate the drive arm on its shaft so that, when the potentiometer is pushed in, the pin and drive arm will engage as shown in Fig. 5.1.

(d) Hold the drive arm stationary and remove the potentiometer. Tighten the drive arm set screws without moving the shaft.

(e) With the pen cable drum rotated fully clockwise (as viewed from front of recorder) against the stop, push the pen holder to the right against the nylon stop. Tighten the four screws in the pen holder.

5.5 Potentiometer Phasing

5.5.1 Phasing Check

(a) Install the potentiometer and push the pen to the left line* on the chart scale.

(b) Turn the recorder OFF and remove the potentiometer cable connector at the pen function amplifier.

(c) Take resistance readings between the pins of the cable connector as shown in Table 5.11. If the resistances are as shown in the table, the potentiometer is properly phased.

If the readings do not agree with those in the table, the potentiometer should be phased as described below.

Plug-In Potentiometer Model Number	Potentiometer Function	Potentiometer Element Location	Measure Between Conn. Pins	Phase Potentiometer for Resistance of
4551	Linear	---	4 to 5	200±25 ohms
4552	Linear Square Root	Upper Lower	4 to 5 1 to 7	200±25 ohms 5 to 10 ohms
4553A-20	Logarithmic (20 db)	---	9 to 15	150±25 ohms
4553-40	Logarithmic (40 db)	---	9 to 15	150±25 ohms
4516-B	Logarithmic (60 db)	---	9 to 15	150±25 ohms
4514-B	Logarithmic (60 db)	---	9 to 15	150±25 ohms
4553-30	Logarithmic (30 db)	---	9 to 15	150±25 ohms

Table 5.11. Potentiometer Resistance Readings

*When checking a square-root potentiometer, push the pen to the first division (1%) above the zero line of the scale (linear paper).

5.5.2 Phasing Procedure

(a) Remove the potentiometer from the recorder and take off the outer case. Also, loosen the potentiometer lock ring nearest the shaft.

(b) Install the potentiometer in the recorder and connect an ohmmeter to the potentiometer cable connector as shown in Table 5.11.

(c) Position the pen as described in step 5.5.1(a).

(d) Turn the potentiometer body for the correct resistance reading and then tighten the locking ring. When the plug-in potentiometer unit consists of two potentiometer elements ganged together, the element nearest the shaft must be phased first and locked before phasing of the other element is attempted.

In some cases it is possible to set the potentiometer element for the proper resistance value, but on the wrong side of the break or null. After a potentiometer element is phased and locked to provide the proper resistance measurements, the pen should be slowly moved up scale while observing the resistance changes. For all potentiometer elements, this resistance should continually increase indicating that the break or null does not occur within the limits of pen motion.

In the case of a square-root potentiometer element, best response is obtained with the break occurring as close to the lower scale pen position as possible.

5.6 Pen System Linearity Check

After phasing a potentiometer, the linearity of the pen system should be checked. Also, periodically check the pen system linearity to ensure the most accurate recordings.

5.6.1 Equipment Needed

(a) Vacuum-tube voltmeter--(Hewlett-Packard Model 410B, or equivalent).

(b) Audio oscillator--(Hewlett-Packard Model 200CD, or equivalent).

(c) Precision attenuator--(General Radio Model 1450 TB, or equivalent).

(d) Precision 40-db fixed pad, 600-ohm input to 6-ohm output.

(e) Interconnecting coaxial cables (BNC connectors).

(f) Signal 1:1 isolation transformer--used if oscillator and recorder share the same ac ground (Triad-JAF-31, or equivalent).

5.6.2 Set-Up Procedure (Refer to Fig. 5.3)

(a) Turn on the equipment and allow 15 minutes for warmup.

(b) Connect the audio oscillator to the input of the precision attenuator.

(c) Connect the input (600-ohm) of the 40-db fixed pad to the output of the precision attenuator.

(d) Connect the output (6-ohm) of the 40-db fixed pad to the BOLOMETER input of the recorder.

(e) Set the BOLOMETER CURRENT adjustment fully counterclockwise.

(f) Place the INPUT switch in the CRYSTAL position to prevent bias current from flowing. Bias current will cause excessive noise to be generated when using the test set-up.

(g) Connect the signal isolation transformer (if needed) between the oscillator output and the precision attenuator.

5.6.3 Operation

The calibration of antenna pattern recorders and their attenuators, etc., is usually performed with reference to the input of a square-law detector. In calibration or measurements using an audio-voltage source, all references should take into account that a square-law detector is not being used and chart db readings should be doubled.

(a) Adjust the frequency of the audio oscillator to the center frequency of the filters in the crystal-bolometer amplifier. This is indicated by maximum pen deflection.

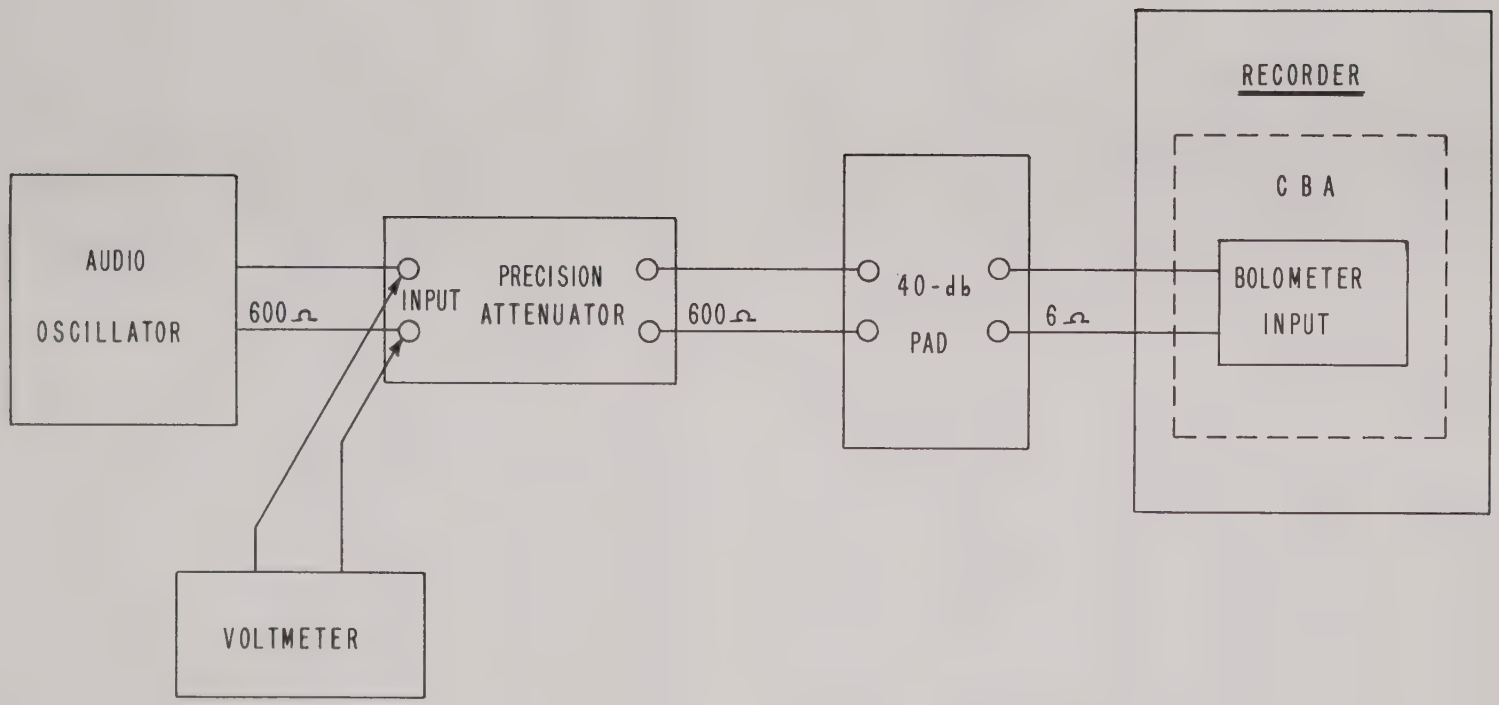


Fig. 5.3. Equipment Arrangement for Pen System Linearity Check

(b) Set and maintain the output voltage of the audio oscillator at 1 volt rms throughout the tests. This should be measured at the input to the precision attenuator.

(c) Adjust the Pen Gain, Pen Tach, and Damping controls of the pen-servo system as described in paragraph 4.3.

(d) For linear and square-root operation, it is necessary to set the PEN ZERO adjustment to obtain zero pen deflection with the crystal-bolometer amplifier ATTENUATOR set in the OFF position.
NOTE: For logarithmic operation, disregard this step.

(e) To check full-scale sensitivity, the test set-up and recorder should be adjusted as follows (set CBA ATTENUATOR to 0):

	Precision Attenuator Setting		Fixed Attenuator	CBA INPUT Signal Level	
	Wide Band	Narrow Band		Wide Band	Narrow Band
Logarithmic	40 db	46 db	40 db	100 μv	50 μv
Linear	80 db	86 db	40 db	1 μv	0.5 μv
Square Root	60 db	66 db	40 db	10 μv	5 μv

(f) With the above set-up and 1-volt rms input to the precision attenuator, it should be possible to obtain the indicated full-scale pen deflection within the range of the CBA GAIN control.

(g) If necessary, return the pen to full-scale with the CBA GAIN control. Leave the other controls as in (e) above.

(h) To check the CBA ATTENUATOR, insert 20 db of additional attenuation with the precision attenuator and mark the pen position. Switch out this attenuation and switch in 10 db with the CBA step ATTENUATOR. The pen should move to within 1% or 0.1 db of the previously marked position. Repeat this procedure for each step of the CBA ATTENUATOR. Do not change the position of the GAIN control as set in (g) above.

(i) Return the pen to full scale--see step (e).

(j) With the combination of the CBA ATTENUATOR and the precision attenuator, it is possible to check the linearity of the full recording range. Maintain the signal level to the CBA high enough at all times to keep a minimum noise level. This is accomplished by switching in attenuation at the CBA attenuator while at the same time switching out attenuation at the precision attenuator.

5.6.4 Interpretation of Accuracy

To interpret the accuracy of the recorder in linear or square-root operation, it is necessary to convert the linear (0-100) scale to a db scale. This may be done easily with a voltage- and power-to-decibel conversion chart.*

Example: 2 db below full scale for linear operation should read 79.4, 4 db = 63.1, etc.

Example: 4 db below full scale for square-root operation should read 79.4, 8 db = 63.1, etc.

(a) The accuracy of the recorder in linear operation is ±0.3% of full scale. In linear operation, full scale is 100 equal divisions on Scientific-Atlanta Style 122 linear chart paper.

(b) The accuracy of the recorder for square-root operation is ±0.5% for the first 40 db (±one-half division).

(c) The accuracy of the recorder for logarithmic operation is ±0.15 db. The error should not be greater than ±0.15 db at any point on the scale.

5.6.5 Precautions

There are several precautions that must be observed when checking the linearity of the recorder.

(a) Make sure that the case of the audio oscillator is not grounded to the recorder other than through the coaxial cables.

(b) Do not allow the crystal-bolometer amplifier to saturate.

(c) When checking linearity "downscale" (below 25 db), the ATTENUATOR on the CBA should be adjusted to minimize noise. To maintain the same input signal level, it will be necessary to remove attenuation in the external precision attenuator equal to twice that inserted with the CBA ATTENUATOR.

5.7 Pen Drive Cable Replacement

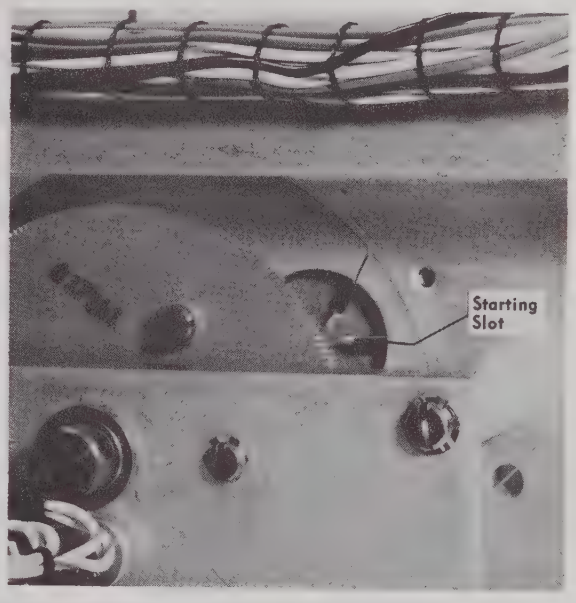
If a new pen drive cable is required, order a replacement through your local Scientific-Atlanta sales representative. The complete description of the cable is "Series 1520 Pen Cable for Model (**) Recorder, Serial No. (**)."

*See inside rear cover of this manual.
**Include Model No. and Serial No. when ordering.

To facilitate cable restringing, remove the recorder head from the cabinet and take off the pen compartment dust cover. Remove the old cable.

(a) Turn the pen cable drum by hand until it is positioned as shown here.

(b) Place one end of the cable in the starting slot and wrap the cable approximately one-half turn clockwise around the drum (facing the rear of the drum).



(c) Pass the cable through the oblong cutout (see Fig. 5.2), over idler pulley "A" (Fig. 5.4), through the hole in the differential synchro plate, and over idler pulley "B."

(d) Pull the cable through the hole in the side plate and across the writing compartment. Loosen the four screws in the pen holder and insert the cable under the metal plate; do not tighten these screws yet.

(e) Feed the cable through the hole in the left-hand end plate, over idler pulleys "C" and "D," and through the oblong hole near pulley "D."

(f) Pass the cable behind the drum, under the shaft, and place the crimped end in the other slot in the drum.

(g) Turn the drum by hand to work the cable onto the drum. The cable is the length required for the proper tension; no tensioning adjustment is necessary.

(h) Rotate the drum by hand clockwise (as viewed from front of recorder) to the mechanical stop.

(i) Push the pen holder to the right against the nylon stop and tighten the four screws in the pen holder.

(j) Replace the pen compartment dust cover.

This completes the pen drive cable replacement.

5.8 Lubrication

All anti-friction bearings used in the assembly of the recorder head are precision bearings (ABEC-1 or better) and are furnished with seals and permanent lubrication.

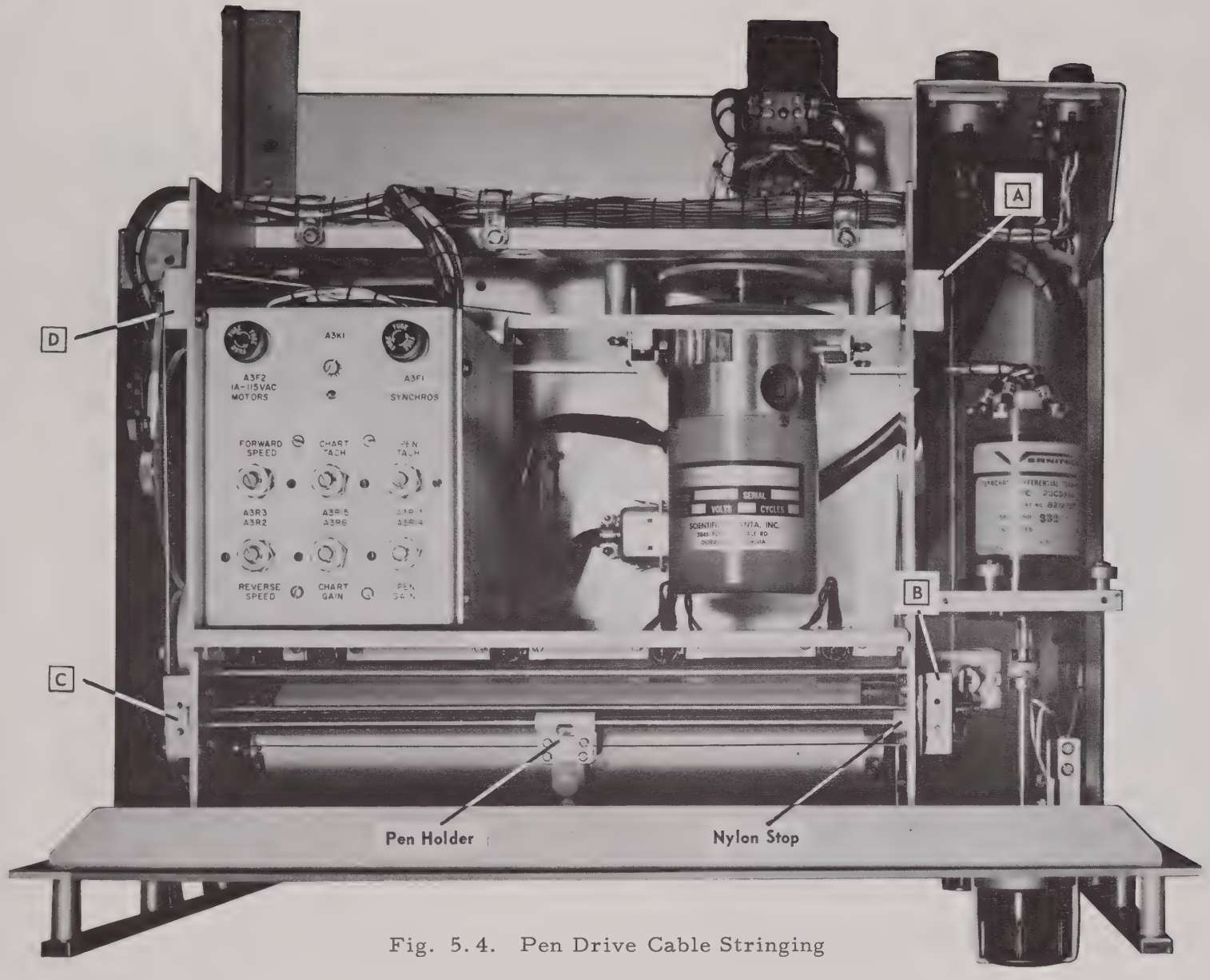


Fig. 5.4. Pen Drive Cable Stringing

These bearings should require no maintenance or lubrication during the normal life of the recorder.

The pen slide bar (Fig. 3.6) should be oiled with one drop of a light machine oil wherever a dark build-up appears on the slide bar, or when dust conditions make it necessary to clean the slide bar.

At least once every three months the eight points indicated by [0] on Fig. 5.5 should be lubricated with light machine oil.

Before lubricating, remove all dust and foreign matter with a vacuum cleaner, brush, or rag. Do not over-oil; one drop at each point should be sufficient.

5.9 Chart Compression Mechanism Installation

The chart compression mechanism can be installed at the factory (Model suffix "C") or in the field. The modification kit should be ordered through your local Scientific-Atlanta sales representative. The complete description of the kit is "Option C Modification Kit for Model (*) Recorder, Serial No. (*)."

(a) Remove the two screws on the inside of the left end plate that hold the idler gear block (see Fig. 3.5). Take off the idler gear and block.

(b) Replace the chart drive gear with the gear included in the kit.

(c) Install the chart-compression gear assembly in place of the idler gear.

(d) Carefully align the gears for proper mesh and minimum backlash. Tighten the two screws.

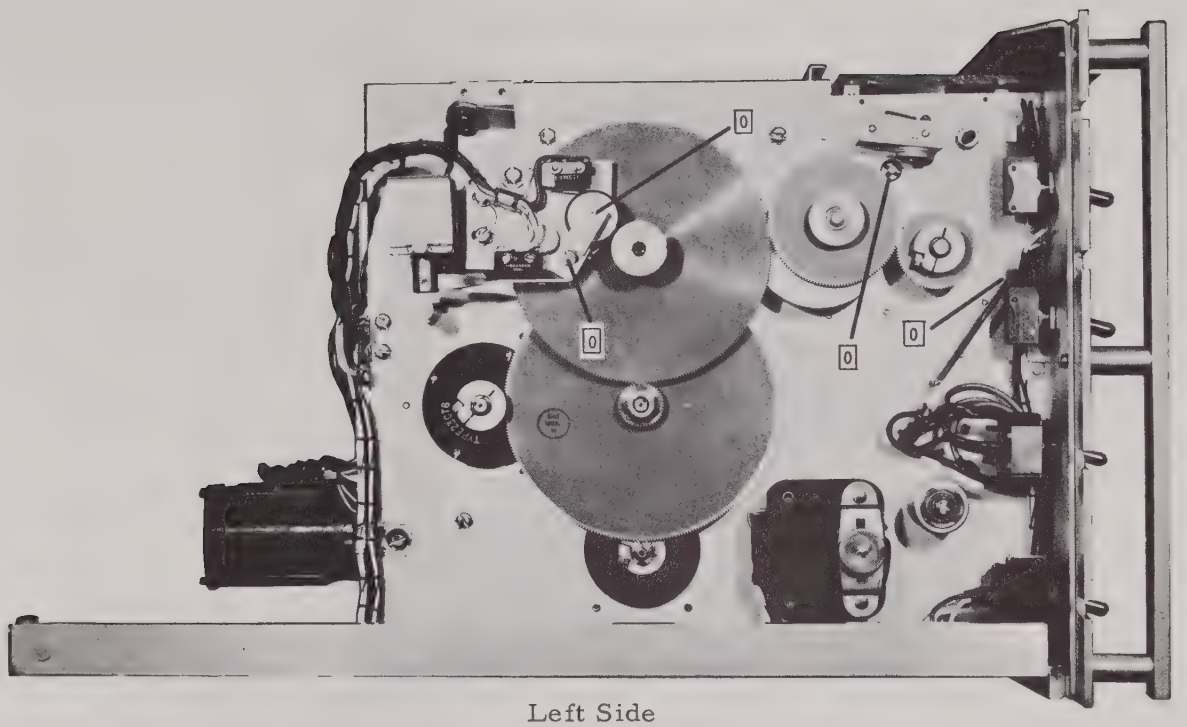
The chart compression kit contains two gears instead of the original one idler gear. Therefore, it is necessary to reverse connections on the chart servomotor, chart tachometer, and CHART ZERO differential control transmitter to maintain the proper chart rotation.

(e) Reverse the connections to terminals 1 and 3 on the chart servomotor.

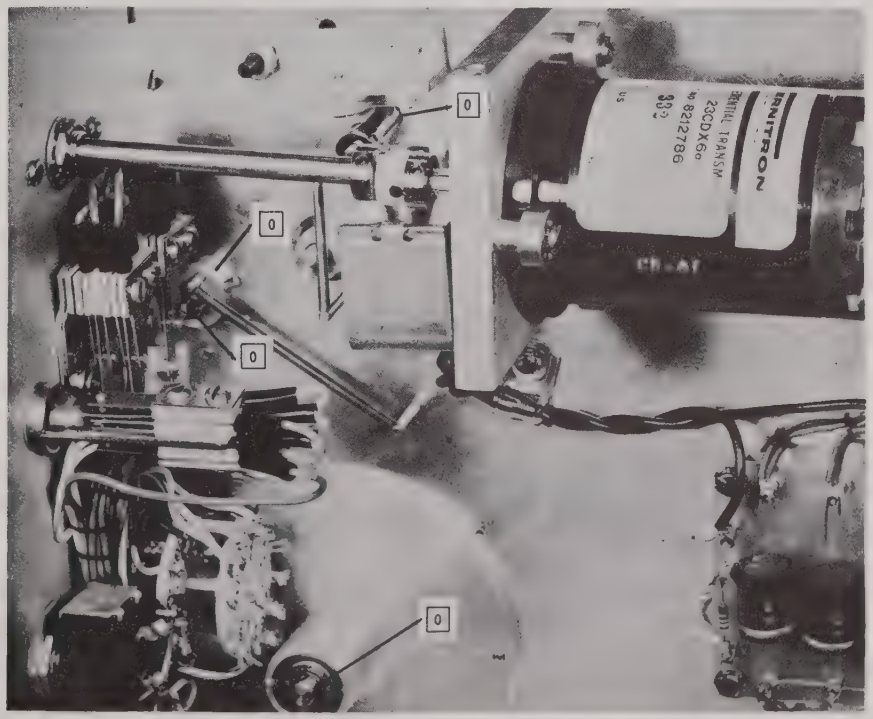
(f) Reverse the connections to terminals 1 and 3 on the chart tachometer.

(g) Reverse the R1 and R3 leads on the CHART ZERO differential control transmitter.

*Include Model No. and Serial No. when ordering.



Left Side



Right Side

Fig. 5.5. Lubrication Points

Refer to Note 3 on Fig. 7.4 for further information. Paragraph 2.7 describes the operation of the recorder with the chart compression modification.

5.10 36:1 Synchro Control Transformer Installation

A 36:1 control transformer can be installed at the factory (Model suffix "S36") or in the field. The modification kit should be ordered through your local Scientific-Atlanta sales representative. The complete description of the kit is "Option S36 Modification Kit for Model (*) Recorder, Serial No. (*)." Detailed installation instructions are included with each kit.

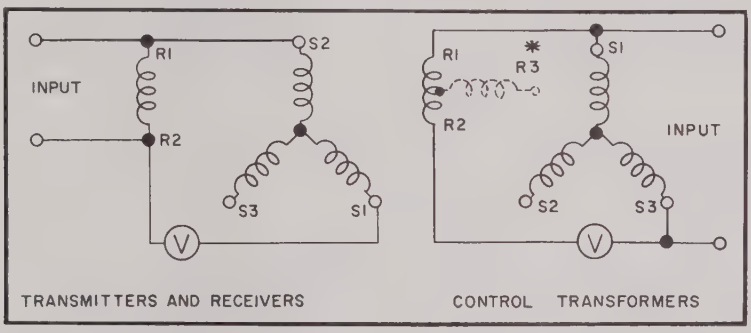
*Include Model No. and Serial No. when ordering.

SYNCHRO ELECTRICAL ZERO

The electrical zero of a synchro is defined as that position of the rotor, with respect to the stator, where the voltage between S1 and S3 is zero and where the voltage from S2 to S1 is in phase with the voltage from R1 to R2.

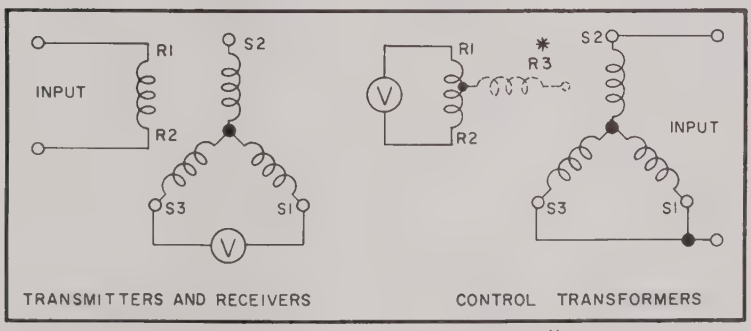
There are two null positions for any synchro. For the correct null, connect the synchro to a voltage source and voltmeter as shown in (A) below; then turn the rotor to determine coarse zero. As the rotor is turned, one null point near the correct electrical zero will be found. To determine the fine electrical zero, connect the synchro as shown in (B) and adjust the rotor slightly until a null is established. This is the exact electrical zero.

(A) COARSE ZERO



*WHEN CDX IS USED AS CT IN S-A TWO-SPEED SYNCHRO PEDESTAL SYSTEMS.

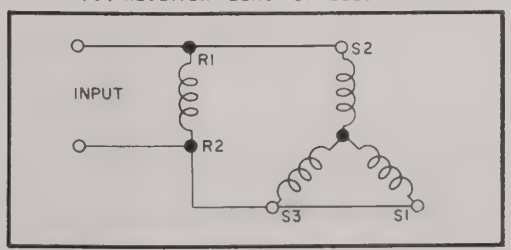
(B) FINE ZERO



*WHEN CDX IS USED AS CT IN S-A TWO-SPEED SYNCHRO PEDESTAL SYSTEMS.

To zero a synchro receiver when its shaft can rotate freely (as in a position indicator), remove all leads from the synchro and reconnect them as shown in (C). The synchro shaft will turn to the electrical zero position when rotor voltage is applied. Do not leave the synchro connected in this manner for more than two minutes, because the synchro will overheat.

(C) RECEIVER ZERO BY ELECTRICAL LOCK



SYNCHRO TROUBLESHOOTING

When connecting or servicing synchro systems, leads may become interchanged. This usually results in rotation opposite to that desired and/or in readings offset by a multiple of 60 degrees. The following table shows the effect and cause of various incorrect connections between a TX and a TR.

If TR rotation with respect to TX is	And With TX on zero, TR reads	Cause is
Opposite	240°	S1-S2 reversed
Opposite	120°	S2-S3 reversed
Opposite	0°	S1-S3 reversed
Same	120°	S1 to S2, S2 to S3, S3 to S1
Same	240°	S1 to S3, S2 to S1, S3 to S2
Same	180°	R1-R2 reversed
Opposite	60°	S1-S2 reversed, R1-R2 reversed
Opposite	300°	S2-S3 reversed, R1-R2 reversed
Opposite	180°	S1-S3 reversed, R1-R2 reversed
Same	300°	S1 to S2, S2 to S3, S3 to S1, and R1-R2 reversed
Same	60°	S1 to S3, S2 to S1, S3 to S2, and R1-R2 reversed

D1155

CHAPTER 6
REPLACEMENT PARTS LISTS

Changes may have been made by hand to the following replacement parts list(s) and/or schematic diagram(s). In general, these changes are appropriate only to the instrument whose serial number appears on the frontispiece of this manual. In addition, an Instruction Manual Change Notice sheet may be inserted immediately following the frontispiece. This sheet describes production changes made to the equipment after the manual was printed. Check this sheet to see if any of the changes apply to your equipment.

Common components may differ from those shown in the parts list. This difference is due to the substitution of a more current part during assembly. In such cases, the type shown in the parts list or the type removed may be used as a replacement.

When ordering parts from Scientific-Atlanta, be sure to include the equipment model number, equipment serial number, and a description of the part.

MANUFACTURERS' CODE LETTERS

Code	Manufacturer	Code	Manufacturer
A	Aerovox	L	Littelfuse
AB	Allen-Bradley	MA	P. R. Mallory
ABE	Amphenol-Borg	MS	Micro Switch
AE	Amperex	MSC	Magnetic Systems
BC	Barber-Coleman	O	Ohmite (LD=Little Devil)
BUS	Bussman	PB	Potter & Brumfield
CE	Cannon	PCC	Phillips Control
CD	Cornell-Dubilier	RCA	Radio Corp. of America
CH	Cutler-Hammer	RE	Royal Electric
CRL	Centralab	RM	Rotron
CWE	Continental-Wirt	SA	Scientific-Atlanta
D	Dage	SC	Switchcraft
DM	Diehl	SII	Sigma Instruments
DP	Dale Products	TO	Tru-Ohm
GC	General Cement	UTC	United Transformer
GE	General Electric	VER	Vernitron
HC	Hoffman Electronics	XX	Any brand diode or transistor which meets JEDEC standards
IMG	IMG Magnetics	ZZ	Any brand tube which meets RETMA standards
IRC	International Resistance		

Component-designation prefix A1 is assigned to a plug-in preamplifier, such as the crystal-bolometer amplifier or dc amplifier. Refer to that unit's instruction manual for its parts list.

PARTS LIST

SERIES 1520 RECORDER
SUBUNIT: SERIES 1555 PEN FUNCTION AMPLIFIER

The component designations are abbreviated. Prefix each component with the number shown below.

A2

Component Designation	Description	Mfr.*	Mfr. Part No.
C1 C28	Capacitor, fixed, electrolytic, 10 µf, 450v	A	PRS 1720
C2 C31 C33	Capacitor, fixed, electrolytic, 5 µf, 25v	A	PWE25005
C3 C6 C14	Capacitor, fixed, Mylar, 0.01 µf, 400v	CD	WMF4S1
C4 C5 C8	Capacitor, fixed, ceramic disc, 0.002 µf, 1000v	CRL	DD-202
C6	See C3		
C7 C8	See C4		
C9	Capacitor, fixed, metallized paper, 0.25 µf, 400v	A	P8292ZN20
C10	Capacitor, fixed, ceramic disc, 50 µf, 1000v	CRL	DD-500
C11 C13	Capacitor, fixed, ceramic disc, 0.003 f, 1000v	CRL	DD-302
C12	Capacitor, fixed, metallized paper, 0.5 µf, 400v	A	P8292ZN21
C13	See C11		
C14	See C3		
C15 C16 C17	Capacitor, fixed, Mylar, 0.047 µf, 100v	CD	WMF1S47
C18	Capacitor, fixed, Mylar, 0.022 µf, 100v	CD	WMF1S22
C19 C21	Capacitor, fixed, Mylar, 0.01 µf, 100v	CD	WMF1S1
C20	Unassigned		
C21	See C19		
C22	Capacitor, fixed, metallized paper, 0.25 µf, 200v	A	P8292ZN11
C23	Capacitor, fixed, electrolytic, 25 µf, 25v	A	PWE25025
C24 C25	Capacitor, fixed, electrolytic, 100 µf, 25v	A	PWE25100
C26	Unassigned		
C27	Capacitor, variable, ceramic trimmer, 8 to 50 pf, 500v	CRL	822-AN
C28	See C1		
C29	Unassigned		
C30	Capacitor, fixed, Mylar, 0.0047 µf, 400v	CD	WMF4D47
C31	See C2		
C32	Capacitor, fixed, Mylar, 0.047 µf, 400v	CD	WMF4S47
C33	See C2		
CR1 CR2 CR6 CR7 CR9 CR10	Diode, silicon	XX	1N816
CR3	Diode, Zener, 6v	HC	RT-6
CR4 CR5 CR11 CR12	Diode, silicon	XX	1N459A
CR6 CR7	See CR1		

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A2

Component Designation	Description	Mfr.*	Mfr. Part No.
CR8	Diode, germanium	XX	1N500
CR9 CR10	See CR1		
CR11 CR12	See CR4		
CR13	Diode, Zener, 6v	HC	RS-6
J1	Connector, receptacle, female, 14 contacts	ABE	57-40140
J2	Connector, receptacle, female, 15 contacts	CE	DAM-15S
J3	Connector, BNC	D	UG-657/U
M1	Meter, 0-50 μa dc	SA	C14400
Q1 Q2	Transistor, germanium, PNP	XX	2N404
Q3	Transistor, silicon, NPN	XX	2N2270
R1	Resistor, fixed, composition, 120 ohms ±10%, 1/4w	O	LD
R2 R65 R70	Resistor, fixed, composition, 6800 ohms ±10%, 1/4w	O	LD
R3	Resistor, fixed, composition, 100 ohms ±10%, 1/4w	O	LD
R4 R8 R31 R32 R50	Resistor, fixed, composition, 10,000 ohms ±10%, 1/4w	O	LD
R5 R11 R38	Resistor, fixed, composition, 1500 ohms ±10%, 1/4w	O	LD
R6	Resistor, fixed, composition, 82 ohms ±10%, 1/4w	O	LD
R7 R17 R23 R25 R55 R56 R79 R81 R89	Resistor, fixed, composition, 1000 ohms ±10%, 1/4w	O	LD
R8	See R4		
R9 R47 R48	Resistor, fixed, composition, 150,000 ohms ±10%, 1/4w	O	LD
R10	Resistor, fixed, composition, 47,000 ohms ±10%, 1/2w	O	LD
R11	See R5		
R12 R15 R18 R34 R35 R42 R44 R45 R71 R72 R77 R84	Resistor, fixed, composition, 100,000 ohms ±10%, 1/4w	O	LD

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A2

Component Designation	Description	Mfr. *	Mfr. Part No.
R13, R46	Resistor, variable, composition, 100,000 ohms ±10%, 2w	O	CLU-1041
R14, R66	Resistor, fixed, composition, 10,000 ohms ±10%, 1/4w	O	LD
R15	See R12		
R16, R22, R78, R82	Resistor, fixed, composition, 100,000 ohms ±10%, 1/2w	O	LD
R17	See R7		
R18	See R12		
R19, R60, R62, R76	Resistor, fixed, composition, 8200 ohms ±10%, 1/4w	O	LD
R20, R24, R74	Resistor, fixed, composition, 1 megohm ±10%, 1/4w	O	LD
R21	Resistor, fixed, composition 100,000 ohms ±10%, 1/4w	O	LD
R22	See R16		
R23	See R7		
R24	See R20		
R25	See R7		
R26	Resistor, fixed, composition, 27,000 ohms ±10%, 1w	O	LD
R27, R88	Resistor, fixed, composition, 330 ohms ±10%, 1/4w	O	LD
R28, R69, R73	Resistor, fixed, composition, 2200 ohms ±10%, 1/4w	O	LD
R29	Resistor, fixed, composition, 220,000 ohms ±10%, 1/4w	O	LD
R30, R86	Resistor, fixed, composition, 120,000 ohms ±10%, 1/4w	O	LD
R31, R32	See R4		
R33, R64, R83	Resistor, fixed, composition, 680 ohms ±10%, 1/4w	O	LD
R34, R35	See R12		
R36	Resistor, fixed, composition, 820 ohms ±10%, 1/4w	O	LD
R37	Resistor, variable, composition, 500 ohms ±10%, 2w	O	CLU-5011
R38	See R5		
R39	Resistor, fixed, composition, 33,000 ohms ±10%, 2w	O	LD
R40	Resistor, fixed, composition, 22,000 ohms ±10%, 1w	O	LD
R41	Resistor, fixed, composition, 330,000 ohms ±10%, 1/2w	O	LD
R42	See R12		
R43	Resistor, fixed, composition, 1.5 megohm ±10%, 1/4w	O	LD
R44, R45	See R12		
R46	See R13		
R47, R48	See R9		
R49, R87	Resistor, fixed, composition, 15,000 ohms ±10%, 1/4w	O	LD
R50	See R4		
R51	Resistor, variable, composition 250,000 ohms ±10%, 2w	O	CLU-2541

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A2

Component Designation	Description	Mfr. *	Mfr. Part No.
R52 R80	Resistor, fixed, composition, 470,000 ohms ±10%, 1/4w	O	LD
R53	Resistor, fixed, composition, 68,000 ohms ±10%, 1/4w	O	LD
R54	Resistor, fixed, composition, 2.2 megohms ±10%, 1/4w	O	LD
R55 R56	See R7		
R57	Resistor, variable, composition, 25,000 ohms, 2w	AB	JLU-2531**
R58 R68 R91	Resistor, fixed, composition, 1800 ohms ±10%, 1/4w	O	LD
R59	Resistor, fixed, composition, 39,000 ohms ±10%, 1/4w	O	LD
R60	See R19		
R61	Resistor, variable, composition, 2500 ohms ±10%, 2w	O	CLU-2521
R62	See R19		
R63 R67	Resistor, fixed, composition, 470 ohms ±10%, 1/4w	O	LD
R64	See R33		
R65	See R2		
R66	See R14		
R67	See R63		
R68	See R58		
R69	See R28		
R70	See R2		
R71 R72	See R12		
R73	See R28		
R74	See R20		
R75	Resistor, variable, composition, 1 megohm ±10%, 2w	O	LD
R76	See R19		
R77	See R12		
R78	See R16		
R79	See R7		
R80	See R52		
R81	See R7		
R82	See R16		
R83	See R33		
R84	See R12		
R85	Resistor, fixed, composition, 4700 ohms ±10%, 1/2w	O	LD
R86	See R30		
R87	See R49		
R88	See R27		
R89	See R7		
R90	Resistor, fixed, composition, factory adjusted, typical value 330,000 ohms ±10%, 1/4w	O	LD
R91	See R58		
R92	Unassigned		
R93	Resistor, fixed, composition, 22,000 ohms ±10%, 1/4w	O	LD
S1	Switch, rotary, 10 poles, 3 positions, non-shorting	CRL	PA-2031
S2	Switch, slide, DPDT	CWE	SW-326

*See "MANUFACTURERS' CODE LETTERS."
**Some units use AB part No. GA1M032S253UC.

PARTS LIST

SERIES 1520 RECORDER
SUBUNIT: SERIES 1555 PEN FUNCTION AMPLIFIER (Continued)

The component designations are abbreviated. Prefix each component with the number shown below.

A2

Component Designation	Description	Mfr.*	Mfr. Part No.
S3	Switch, rotary, 3 poles, 5 positions, non-shorting	CRL	PA-2007
V1 thru V7	Nuvistor, high mu	RCA	13CW4

*See "MANUFACTURERS' CODE LETTERS."

PARTS LIST

SERIES 1520 RECORDER
SUBUNIT: RECTANGULAR PATTERN RECORDER HEAD

The component designations are abbreviated. Prefix each component with the number shown below.

A3

Component Designation	Description	Mfr.*	Mfr. Part No.
A1	Potentiometer, linear	SA	4551
	Potentiometer, linear-square root	SA	4552
	Potentiometer, logarithmic	SA	4553
B1	Synchro, control differential transmitter	VER	23CDX6a
B2 B3 B4	Synchro, control transformer	VER	23CT6
B5 B7	Motor, servo with ac tachometer	DM	FPE-25L-105-18
B6	Motor, 115v, 60 cps	BC	YAA6447
B7	See B5		
C1 C2 C3	Capacitor, fixed, metallized paper, 0.05 μf, 600v	A	P8292ZN27
C4 C7 C8	Capacitor, fixed, metallized paper, 1.0 μf, 200v	A	P8292ZN13
C5 C6	Capacitor, fixed, ceramic disc, 0.01 μf, 1000v	CRL	DD-1032
C7 C8	See C4		
DS1 thru DS4	Bulb, incandescent, 12v, bayonet-base	GE	57X
F1 F2	Fuse, 3AG, 1a	L	312001
F3	Fuse, 3AG, 2a, slow blow	L	313002
J1 J2 J3	Connector, receptacle, female, 8 contacts	ABE	MS3102A-20-7S
J4	Connector, receptacle, female, 19 contacts	ABE	MS3102A-22-14S
J5 J6	Connector, receptacle, female, 2 contacts	ABE	MS3102A-12S-3S
J7	Connector, receptacle, female, 5 contacts	ABE	MS3102A-14S-5S
J8	Connector, receptacle, female, 14 contacts	ABE	57-40140
J9	Connector, receptacle, 2 contacts	CM	S-302AB
K1	Relay, DPDT, 115v ac, 60 cps coil	PB	KA11AY
K2 K3	Solenoid, 115v ac, 60 cps	PCC	41-C-115-60
P1	Connector, cable, male, 3 pins, ac power	RE	K-5146
P2	Connector, cable, male, 15 pins	CE	DAM-15P

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A3

Component Designation	Description	Mfr.*	Mfr. Part No.
R1	Resistor, fixed, composition, 39,000 ohms ±10%, 1/4w	O	LD
R2	Resistor, variable, composition, 10,000 ohms ±10%, 2w	O	CLU-1031
R3			
R6			
R13			
R15			
R4	Resistor, fixed, composition, 150,000 ohms ±10%, 1/4w	O	LD
R5	Resistor, fixed, wirewound, 1 ohm ±5%, 2w	IRC	BWH-2
R6	See R2		
R7	Unassigned		
R8			
R9	Resistor, fixed, composition, 47 ohms ±10%, 1/2w	O	LD
R10	Resistor, fixed, composition, 47,000 ohms ±10%, 1/4w	O	LD
R11	Unassigned		
R12			
R13	See R2		
R14	Resistor, variable, composition, 5000 ohms ±10%, 2w	O	CLU-5021
R15	See R2		
S1	Switch, rotary, 5 poles, 3 positions, non-shorting	CRL	PA-2015
S2	Switch, rotary, 6 poles, 5 positions, non-shorting	CRL	PA-2021
S3	Switch, toggle, DPDT	CH	7565K5
S4	Switch, "Lev-R," DPDT	SC	13036L
S5	Switch, Micro, SPDT	MS	11SM1-T
S8			
S6	Switch, pushbutton, DPDT	SC	1006
S7			
S8	See S5		
S9	Switch, toggle, SPST	GC	1330
S10			
S12			
S11	Switch, toggle, SPDT	CH	7505K4
S12	See S9		
S13	Switch, toggle, DPST	CH	7561K4
XF1	Fuse holder, panel mounting	BUS	HKP
XF2			
XF3			

*See "MANUFACTURERS' CODE LETTERS."

PARTS LIST

SERIES 1520 RECORDER
SUBUNIT: SERVO AMPLIFIER AND POWER SUPPLY

The component designations are abbreviated. Prefix each component with the number shown below.

A4

Component Designation	Description	Mfr.*	Mfr. Part No.
B1	Blower, 115v ac, 50/60 cps	RM	"Filter Fan"
C1 C9 C13 C19 C20	Capacitor, fixed, electrolytic, 100 µf, 15v	A	PWE15100
C2 C8 C11 C31 C32	Capacitor, fixed, electrolytic, 25 µf, 25v	A	PWE25025
C3 thru C6 C15 C16 C35	Capacitor, fixed, metallized paper, 2.0 µf, 200v	A	P8292ZN14
C7 C29 C30	Capacitor, fixed, Mylar, 0.47 µf, 100v	CD	WMF1P47
C8	See C2		
C9	See C1		
C10 C21 C34	Capacitor, fixed, metallized paper, 1.0 µf, 200v	A	P8292ZN13
C11	See C2		
C12 C28	Capacitor, fixed, Mylar, 0.1 µf, 100v	CD	WMF1P1
C13	See C1		
C14 C33	Capacitor, fixed, electrolytic, 200 µf, 6v	A	PWE6200
C15 C16	See C3		
C17	Capacitor, fixed, electrolytic, 500 µf, 25v	CD	BR500-25
C18 C41	Capacitor, fixed, electrolytic, 100 µf, 25v	A	PWE25100
C19 C20	See C1		
C21	See C10		
C22 C23 C27	Capacitor, fixed, electrolytic, 50 µf, 350v	A	PRS1680
C24 C26	Capacitor, fixed, Mylar, 0.1 µf, 400v	CD	WMF4P1
C25 C40	Capacitor, fixed, disc, 470 pf, 1000v	CRL	DD-471
C26	See C24		
C27	See C22		
C28	See C12		
C29 C30	See C7		
C31 C32	See C2		
C33	See C14		
C34	See C10		
C35	See C3		

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A4

Component Designation	Description	Mfr.*	Mfr. Part No.
C36	Capacitor, fixed, electrolytic, 20 µf, 500v	A	PRS 1830
C37	Capacitor, fixed, electrolytic, 3450 µf, 75v	MA	CG3451U75D1
C38	Capacitor, fixed, electrolytic, 500 µf, 50v	CD	BR500-50
C39	Capacitor, fixed, electrolytic, 4500 µf, 50v	MA	CG452U50D1
C40	See C25		
C41	See C18		
C42	Capacitor, fixed, ceramic disc, 0.001 µf, 1000v	CRL	DD-102
C43**	Capacitor, fixed, electrolytic, 10 µf, 50v	A	PWE 5010
C44	Capacitor, fixed, ceramic disc, 0.01 µf, 150V	CRL	DDM-103
CR1 thru CR14 CR21 thru CR26 CR38 CR39	Diode, silicon, reference	XX	1N816
CR15 CR27	Diode, germanium	GE	1N91
CR16 CR17 CR18 CR28 CR40	Diode, Zener	HC	RS-6
CR19 CR20	Diode, silicon	XX	1N2484
CR21 thru CR26	See CR1		
CR27	See CR15		
CR28	See CR16		
CR29 thru CR32	Diode, silicon	XX	1N3209
CR33	Diode, silicon	XX	1N1777
CR34 thru CR37	Diode, silicon	XX	1N1220
CR38 CR39	See CR1		
CR40	See CR16		
F1	Fuse, 3AG, 2a	L	312002
F2	Fuse, 3AG, 3a, slow blow	L	313003
F3	Fuse, 3AG, 0.5a, slow blow	L	31300.5
J1	Connector, receptacle, male, 19 pins	ABE	MS3102A-22-14P
J2	Connector, receptacle, female, 10 contacts	ABE	MS3102A-18-1S
J3	Connector, receptacle, female, 14 contacts	ABE	MS3102A-20-27S
L1	Choke, 20 hy, 40 ma	UTC	H-71

*See "MANUFACTURERS' CODE LETTERS."
**Serial No. 58 and above.

The component designations are abbreviated. Prefix each component with the number shown below.

A4

Component Designation	Description	Mfr.*	Mfr. Part No.
P1	Connector, cable, female, 19 contacts	ABE	MS3106A-22-14S
P2	Connector, cable, male, 10 pins	ABE	MS3106A-18-1P
P3	Connector, cable, male, 14 pins	ABE	MS3106A-20-27P
Q1, Q4, Q5, Q27	Transistor, germanium, PNP	XX	2N404
Q2, Q6, Q23, Q26, Q28, Q29	Transistor, germanium, NPN	XX	2N1605
Q3, Q11 thru Q14	Transistor, silicon, NPN	XX	2N2270
Q4, Q5	See Q1		
Q6	See Q2		
Q7, Q8, Q16, Q17	Transistor, germanium, PNP	XX	2N1183A
Q9, Q10, Q18, Q19	Transistor, germanium, PNP	XX	2N174
Q11 thru Q14	See Q3		
Q15	Transistor, germanium, PNP	XX	2N404A
Q16, Q17	See Q7		
Q18, Q19	See Q9		
Q20, Q25	Transistor, germanium, PNP	XX	2N441
Q21, Q22, Q24	Transistor, germanium, PNP	XX	2N1183
Q23	See Q2		
Q24	See Q21		
Q25	See Q20		
Q26	See Q2		
Q27	See Q1		
Q28, Q29	See Q2		
Q30	See Q3		
R1, R3, R32, R34, R46	Resistor, fixed, composition, 22,000 ohms ±10%, 1/4w	O	LD

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A4

Component Designation	Description	Mfr.*	Mfr. Part No.
R2	Resistor, fixed, composition, 220 ohms ±10%, 1/4w	O	LD
R3	See R1		
R4 R14 R24 R30 R35 R59 R70 R71 R72	Resistor, fixed, composition, 10,000 ohms ±10%, 1/4w	O	LD
R5 R36	Resistor, fixed, composition, 1800 ohms ±10%, 1/4w	O	LD
R6 R25 R27 R69	Resistor, fixed, composition, 4700 ohms ±10%, 1/4w	O	LD
R7	Resistor, fixed, composition, 220,000 ohms ±10%, 1/4w	O	LD
R8	Resistor, fixed, composition, 330,000 ohms ±10%, 1/4w	O	LD
R9	Resistor, fixed, composition, 12,000 ohms ±10%, 1/4w	O	LD
R10 R13 R52	Resistor, fixed, composition, 1 megohm ±10%, 1/4w	O	LD
R11 R15	Resistor, fixed, composition, 470,000 ohms ±10%, 1/4w	O	LD
R12	Resistor, fixed, composition, factory adjusted, typical value 4700 ohms ±10%, 1/4w	O	LD
R13	See R10		
R14	See R4		
R15	See R11		
R16 R53 R61	Resistor, fixed, composition, 47,000 ohms ±10%, 1/4w	O	LD
R17 R18	Resistor, fixed, composition, 150,000 ohms ±10%, 1/4w	O	LD
R19 R20	Resistor, fixed, composition, 100,000 ohms ±10%, 1/4w	O	LD
R21	Resistor, fixed, composition, 39,000 ohms ±10%, 1/4w	O	LD
R22 R23 R28 R29 R95 R96 R97	Resistor, fixed, composition, 3300 ohms ±10%, 1/4w	O	LD
R24	See R4		
R25	See R6		
R26	Resistor, fixed, composition, 470 ohms ±10%, 1/4w	O	LD
R27	See R6		
R28 R29	See R23		
R30	See R4		
R31	Resistor, fixed, composition, 68,000 ohms ±10%, 1/4w	O	LD
R32	See R1		
R33	Resistor, fixed, composition, 270 ohms ±10%, 1/4w	O	LD
R34	See R1		
R35	See R4		
R36	See R5		

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A4

Component Designation	Description	Mfr.*	Mfr. Part No.
R37 R48 R49	Resistor, fixed, composition, 1000 ohms ±10%, 1/4w	O	LD
R38 R39 R73 R74 R85	Resistor, fixed, composition, 470 ohms ±10%, 1/2w	O	LD
R40 R77	Resistor, fixed, wirewound, 400 ohms ±5%, 5w	TO	VAL-5
R41	Resistor, fixed, composition, 330 ohms ±10%, 1/2w	O	LD
R42 R43 R75 R76	Resistor, fixed, composition, 33 ohms ±10%, 1/2w	O	LD
R44 R45 R78 R79 R93	Resistor, fixed, wirewound, 1 ohm ±5%, 5w	TO	VAL-5
R46	See R1		
R47 R89	Resistor, fixed, composition, 8200 ohms ±10%, 1/4w	O	LD
R48 R49	See R37		
R50	Resistor, fixed, composition, 33,000 ohms ±10%, 1w	O	LD
R51	Resistor, fixed, composition, 47,000 ohms ±10%, 1/2w	O	LD
R52	See R10		
R53	See R16		
R54 R62 R67	Resistor, fixed, composition, 33,000 ohms ±10%, 1/4w	O	LD
R55	Resistor, fixed, composition, 15,000 ohms ±10%, 1/4w	O	LD
R56 R60	Resistor, fixed, composition, 120,000 ohms ±10%, 1/4w	O	LD
R57	Resistor, fixed, composition, 82,000 ohms ±10%, 2w	O	LD
R58 R65	Resistor, fixed, carbon film, 150,000 ohms ±1%, 1w	DP	DCF-1
R59	See R4		
R60	See R56		
R61	See R16		
R62	See R54		
R63 R68 R104	Resistor, fixed, composition, 2200 ohms ±10%, 1/4w	O	LD
R64	Resistor, fixed, carbon film, 80,600 ohms ±1%, 1/4w	DP	DCF-1/4
R65	See R58		
R66	Resistor, fixed, composition, 10,000 ohms ±10%, 1w	O	LD
R67	See R54		
R68	See R63		
R69	See R6		
R70 R71 R72	See R4		
R73 R74	See R38		
R75 R76	See R42		

*See "MANUFACTURERS' CODE LETTERS."

The component designations are abbreviated. Prefix each component with the number shown below.

A4

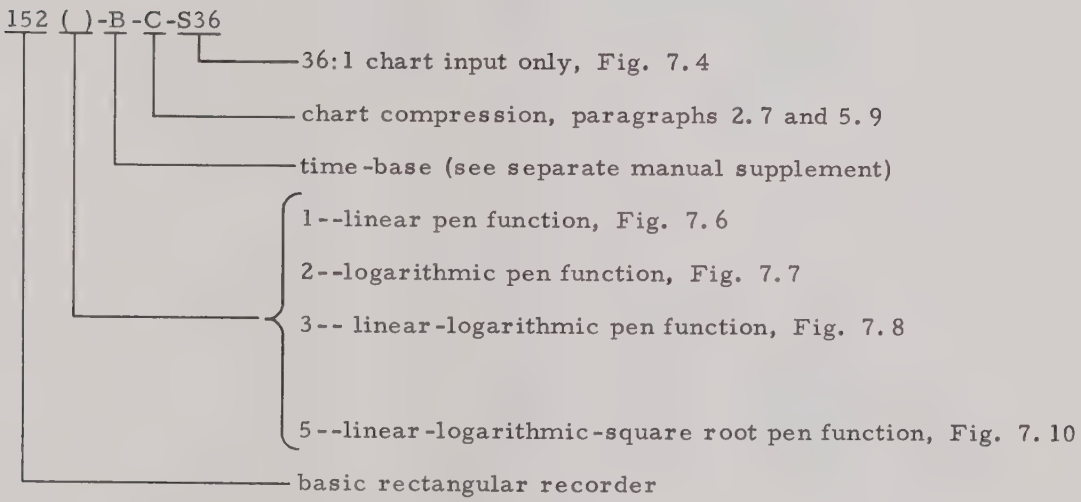
Component Designation	Description	Mfr.*	Mfr. Part No.
R77	See R40		
R78	See R44		
R79			
R80	Resistor, fixed, wirewound, 1.5 ohms ±5%, 10w	TO	VAL-10
R81			
R88			
R82	Resistor, fixed, composition, 1000 ohms ±10%, 1w	O	LD
R83	Resistor, fixed, composition, 2700 ohms ±10%, 1/2w	O	LD
R84	Resistor, variable, composition, 1000 ohms ±10%, 2w	O	CLU-1021
R85	See R38		
R86	Resistor, fixed, composition, 1800 ohms ±10%, 1/2w	O	LD
R87	Resistor, fixed, composition, 3300 ohms ±10%, 1/2w	O	LD
R88	See R80		
R89	See R47		
R90	Resistor, fixed, composition, 560 ohms ±10%, 1/4w	O	LD
R91	Resistor, fixed, composition, 22 ohms ±10%, 2w	O	LD
R92	Resistor, fixed, composition, 1200 ohms ±10%, 1/2w	O	LD
R93	See R44		
R94	Resistor, fixed, composition, 680 ohms ±10%, 1/2w	O	LD
R95	See R22		
R96			
R97			
R98	Resistor, fixed, wirewound, 1200 ohms ±5%, 3w	TO	VAL-3
R100			
R99	Resistor, variable, composition, 500 ohms ±10%, 2w	O	CLU-5011
R100	See R98		
R101	Resistor, fixed, composition, 680 ohms ±10%, 1/4w	O	LD
R102	Resistor, fixed, composition, 10 ohms ±10%, 2w	O	LD
R103			
R104	See R63		
R105	Resistor, fixed, composition, 39,000 ohms ±10%, 1/4w	O	LD
R106	Resistor, fixed, composition, 470 ohms ±10%, 1/2W	O	LD
T1	Transformer, power	MSC	A1-5636
T2	Transformer, output	UTC	A-23
T3			
V1	Tube, electron	ZZ	6BX7
V2	Tube, gas regulating	AE	8228
V3			
XF1	Fuse holder, panel mounting	BUS	HKP
XF2			
XF3			

*See "MANUFACTURERS' CODE LETTERS."

CHAPTER 7
SCHEMATIC DIAGRAMS

This chapter contains schematic diagrams for all models of the Series 1520 Rectangular Recorders. Disregard any information that does not apply to your recorder.

Rectangular Recorder Model-Numbering System


152 ( )-B-C-S36
36:1 chart input only, Fig. 7.4
chart compression, paragraphs 2.7 and 5.9
time-base (see separate manual supplement)
1--linear pen function, Fig. 7.6
2--logarithmic pen function, Fig. 7.7
3-- linear-logarithmic pen function, Fig. 7.8
5--linear-logarithmic-square root pen function, Fig. 7.10
basic rectangular recorder

2072-C16647A

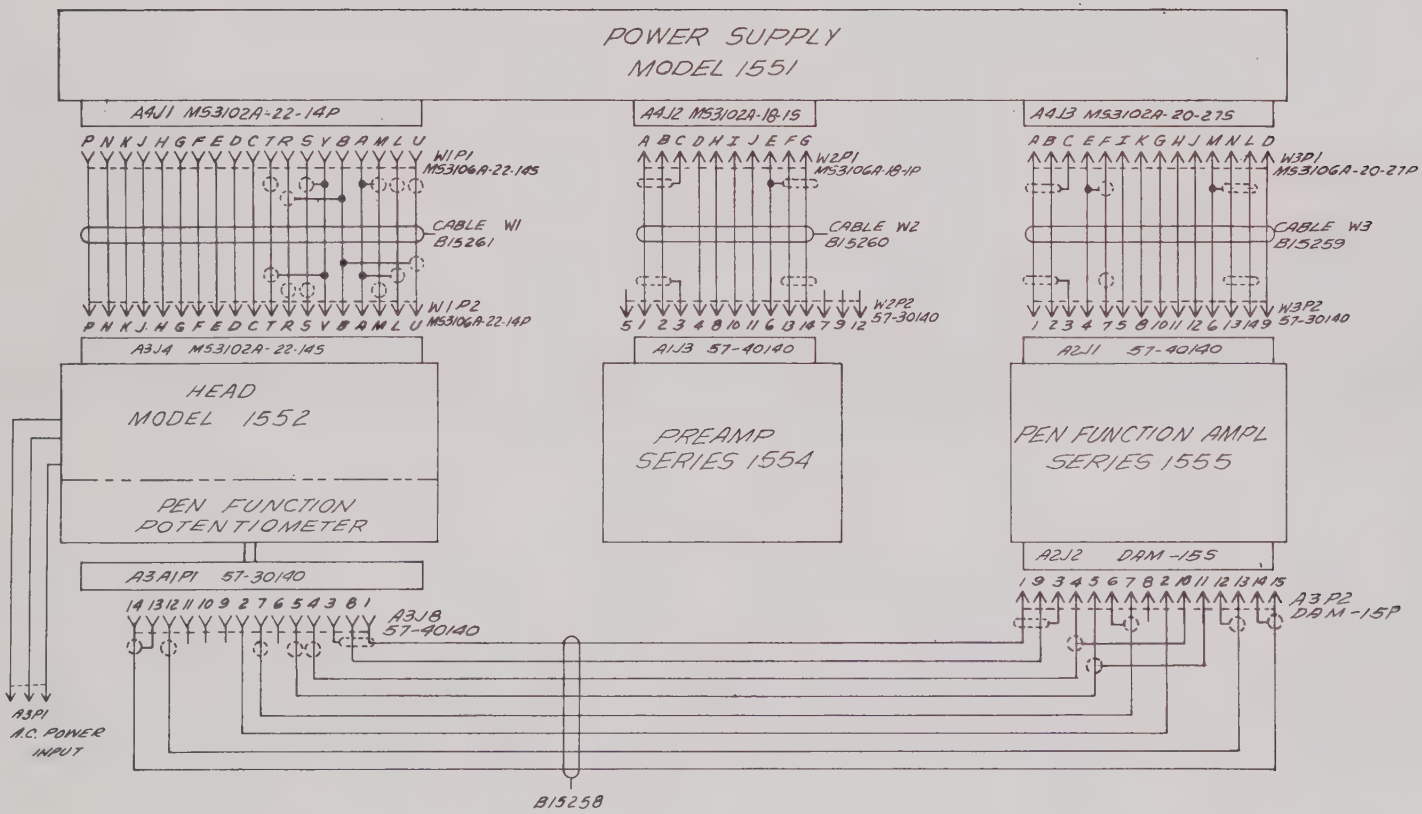


Fig. 7.1 Rectangular Recorder
Cabling Diagram

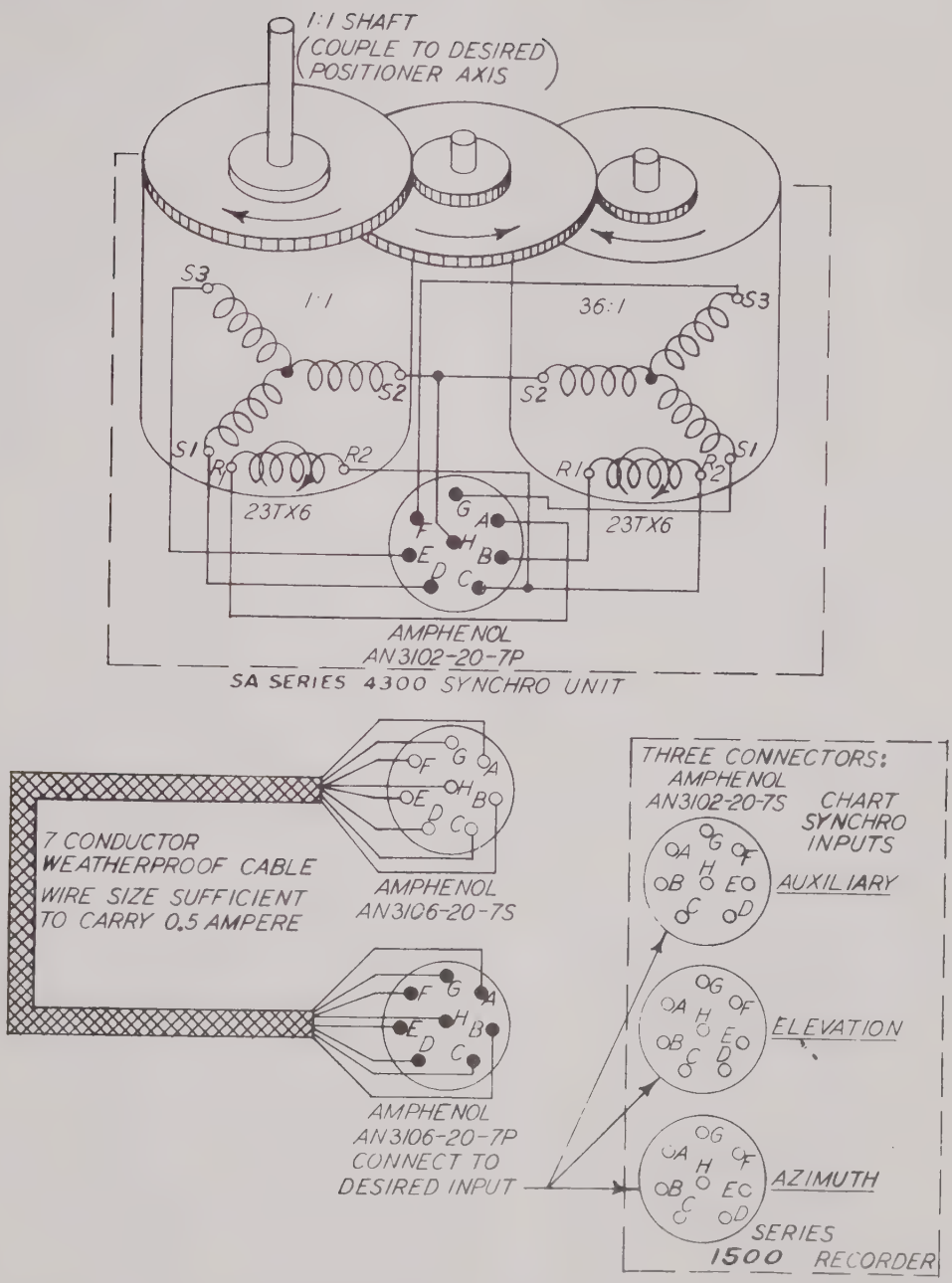


CHART SYSTEM CONNECTIONS

Fig. 7.2. Chart System Connections for S2 Common

1520/A19649

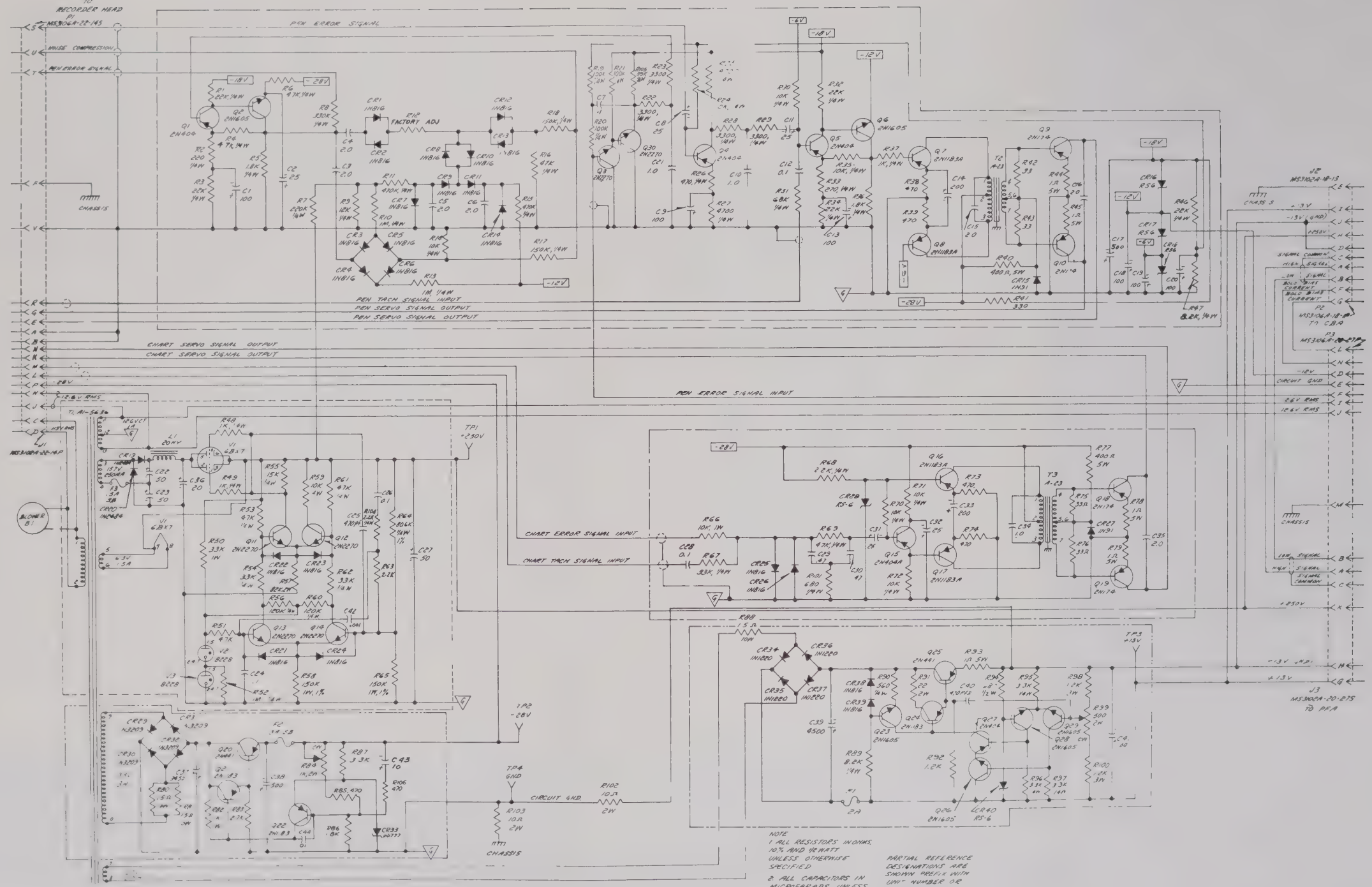

TO RECORDER HEAD
PEN ERROR SIGNAL
PEN TACH SIGNAL INPUT
PEN SERVO SIGNAL OUTPUT
PEN SERVO SIGNAL OUTPUT
CHART SERVO SIGNAL OUTPUT
CHART SERVO SIGNAL OUTPUT
PEN ERROR SIGNAL INPUT
CHART ERROR SIGNAL INPUT
CHART TACH SIGNAL INPUT
CHASSIS
CIRCUIT GND
FACTORY ADJ
NOTE
1 ALL RESISTORS IN OHMS, 10% AND ½ WATT UNLESS OTHERWISE SPECIFIED.
2. ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE SPECIFIED
PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. REFER WITH UNIT NUMBER OR SUBASSEMBLY DESIGNATION (S) OR BOTH FOR COMPLETE DESIGNATION

Fig. 7.3. Power Supply and Servo Amplifier Schematic Diagram

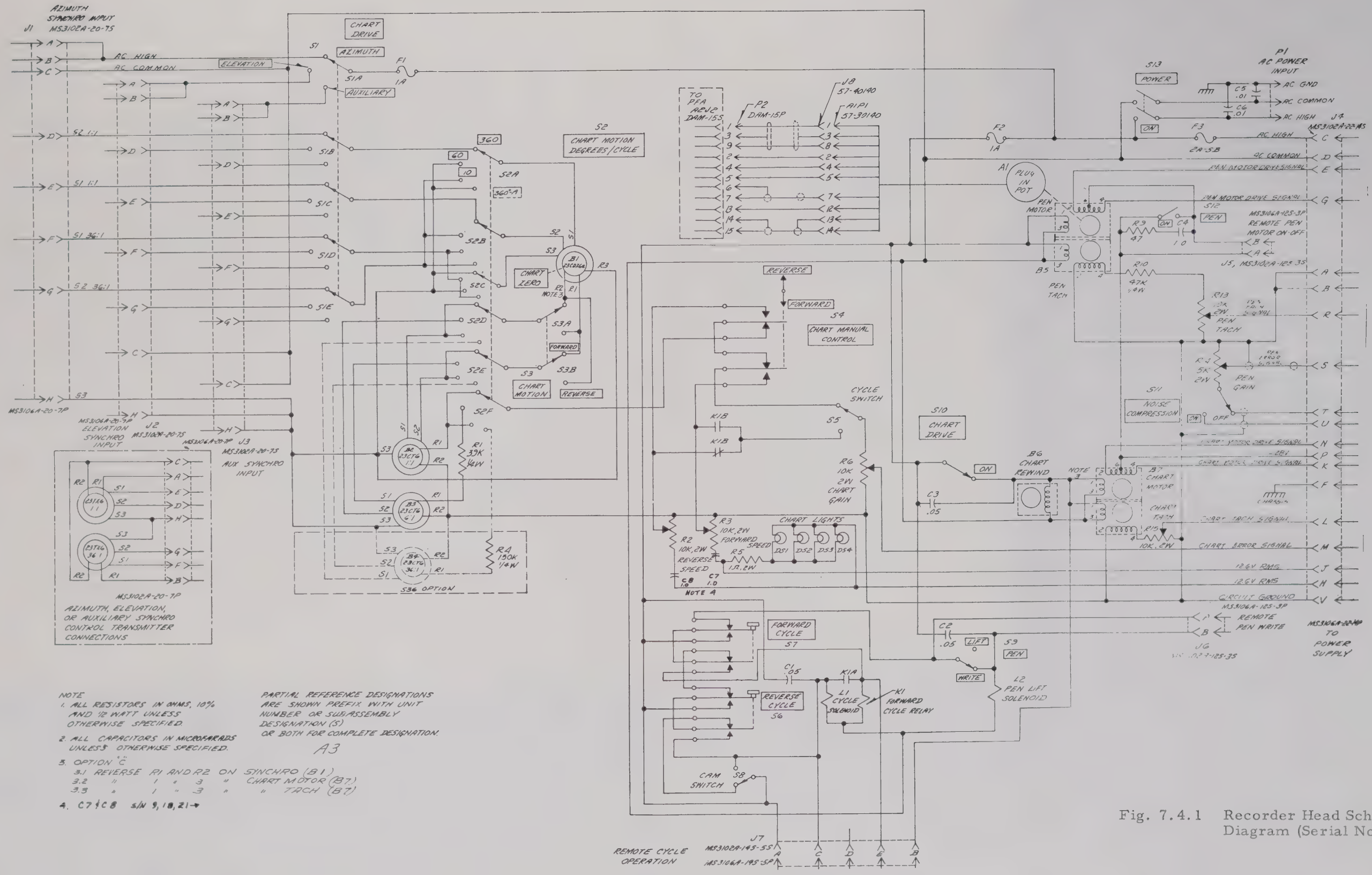
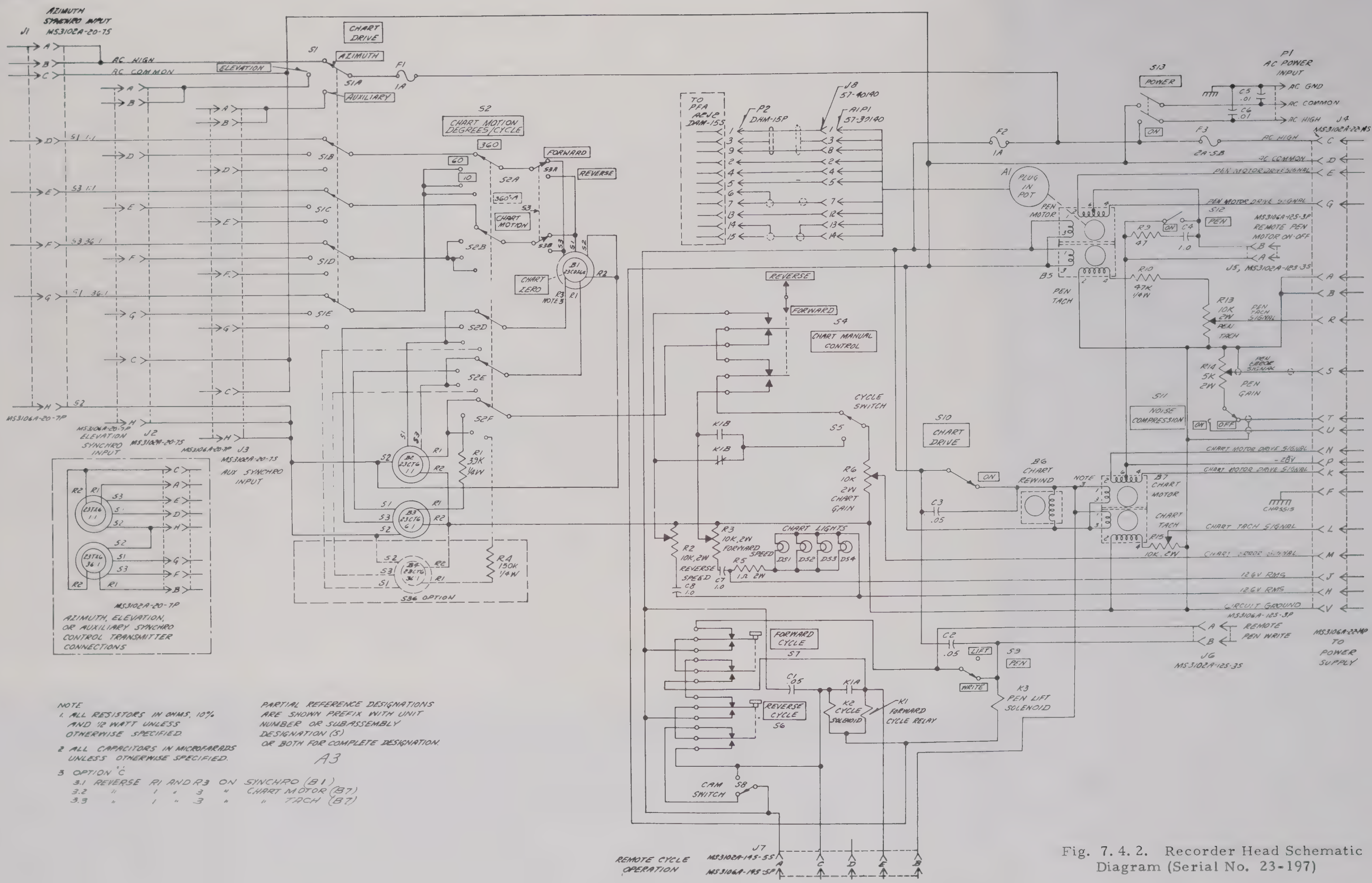


Fig. 7.4.1 Recorder Head Schematic Diagram (Serial No. 1-22)

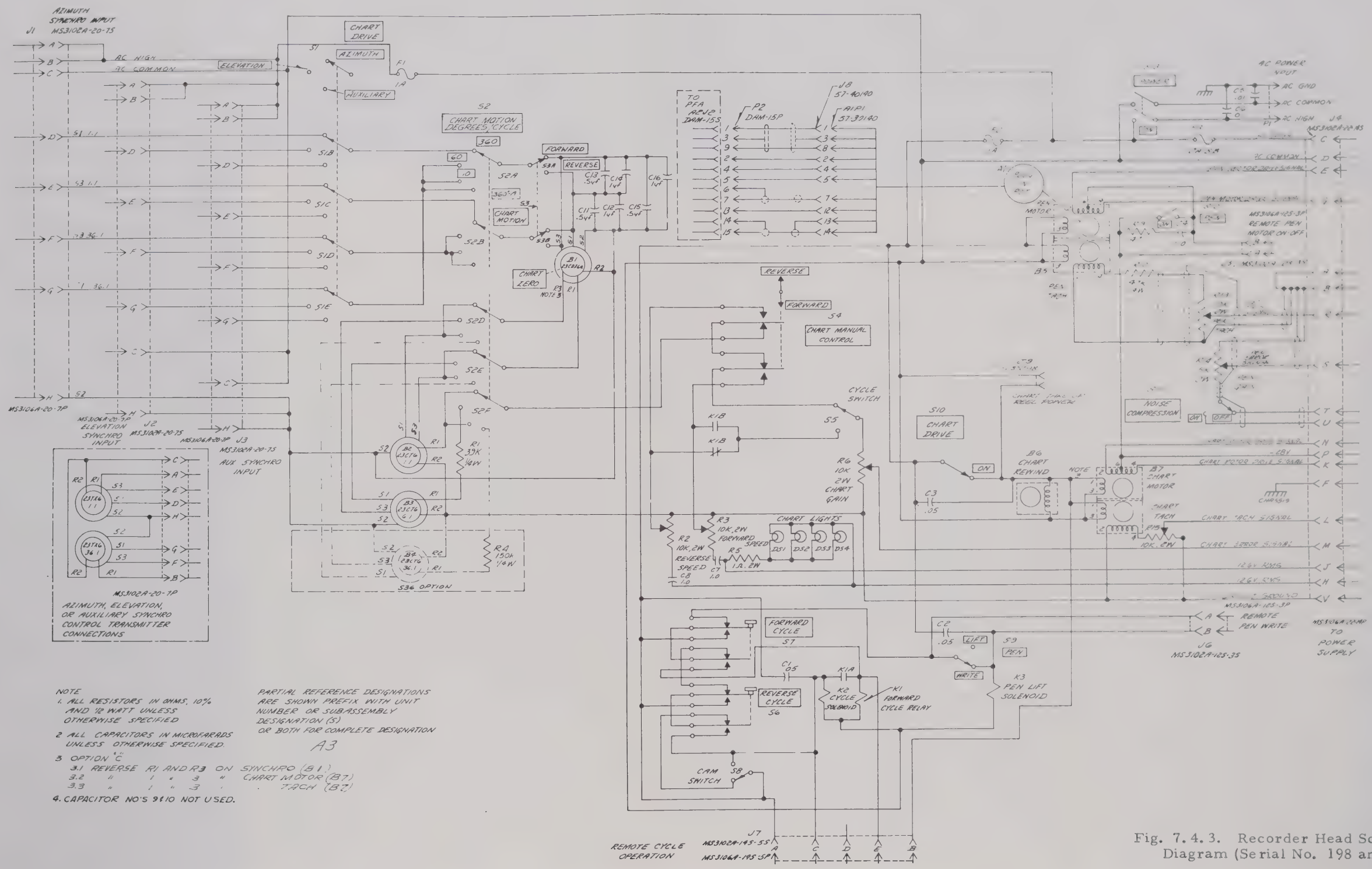


NOTE
1. ALL RESISTORS IN OHMS, 10% AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.
2. ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. OPTION 'C'
   - 3.1 REVERSE R1 AND R3 ON SYNCHRO (B1)
   - 3.2 " 1 " 3 " CHART MOTOR (B7)
   - 3.3 " 1 " 3 " " TACH (B7)

PARTIAL REFERENCE DESIGNATIONS ARE SHOWN PREFIX WITH UNIT NUMBER OR SUBASSEMBLY DESIGNATION (S) OR BOTH FOR COMPLETE DESIGNATION.

A3

Fig. 7.4.2. Recorder Head Schematic Diagram (Serial No. 23-197)

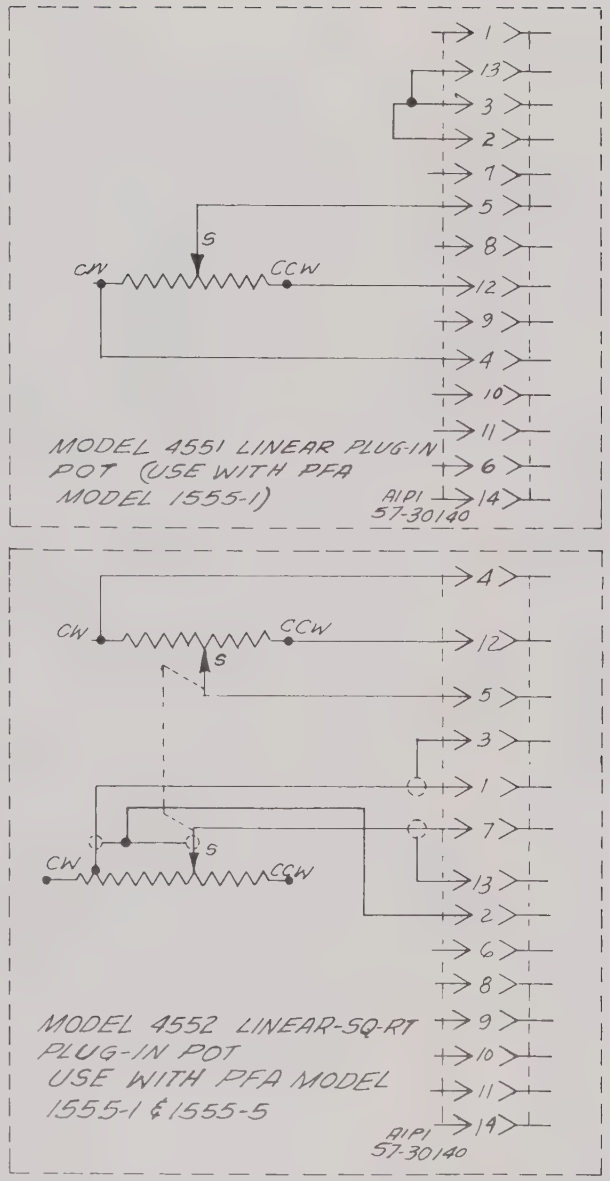


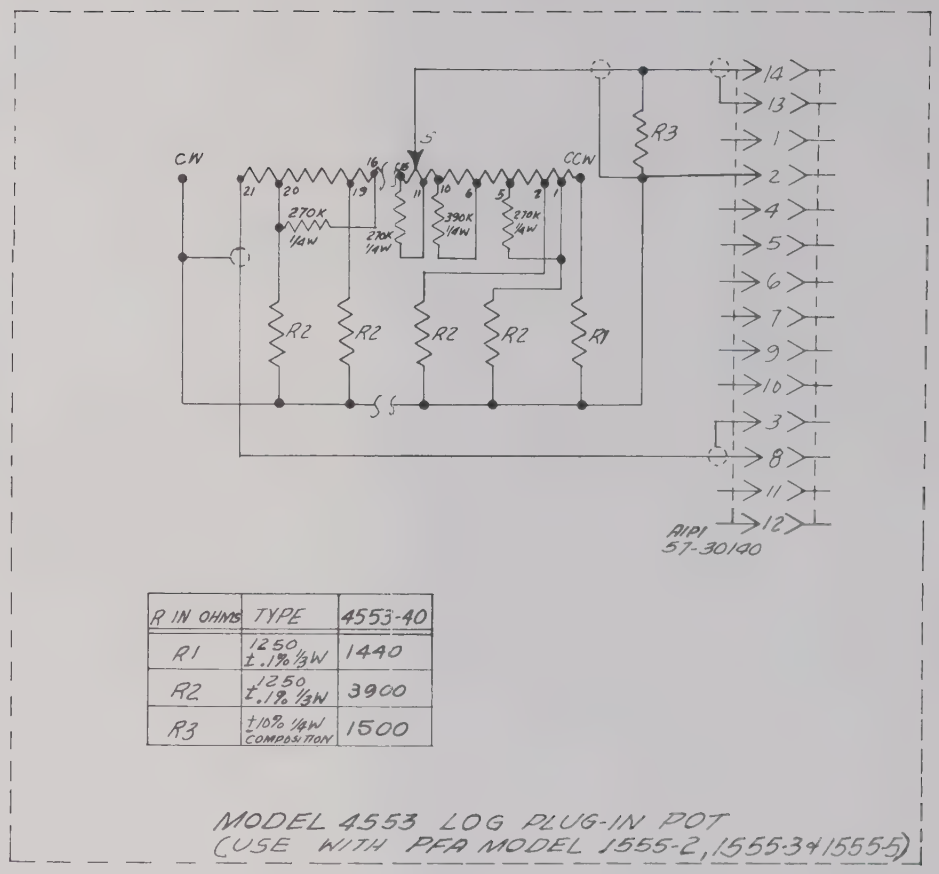
NOTE
1. ALL RESISTORS IN OHMS, 10% AND 1/2 WATT UNLESS OTHERWISE SPECIFIED
2. ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. OPTION "C"
   - 3.1 REVERSE R1 AND R3 ON SYNCHRO (B1)
   - 3.2 " 1 " 3 " CHART MOTOR (B7)
   - 3.3 " 1 " 3 " TACH (B7)
4. CAPACITOR NO'S 9 & 10 NOT USED.

PARTIAL REFERENCE DESIGNATIONS ARE SHOWN PREFIX WITH UNIT NUMBER OR SUBASSEMBLY DESIGNATION (S) OR BOTH FOR COMPLETE DESIGNATION

A3

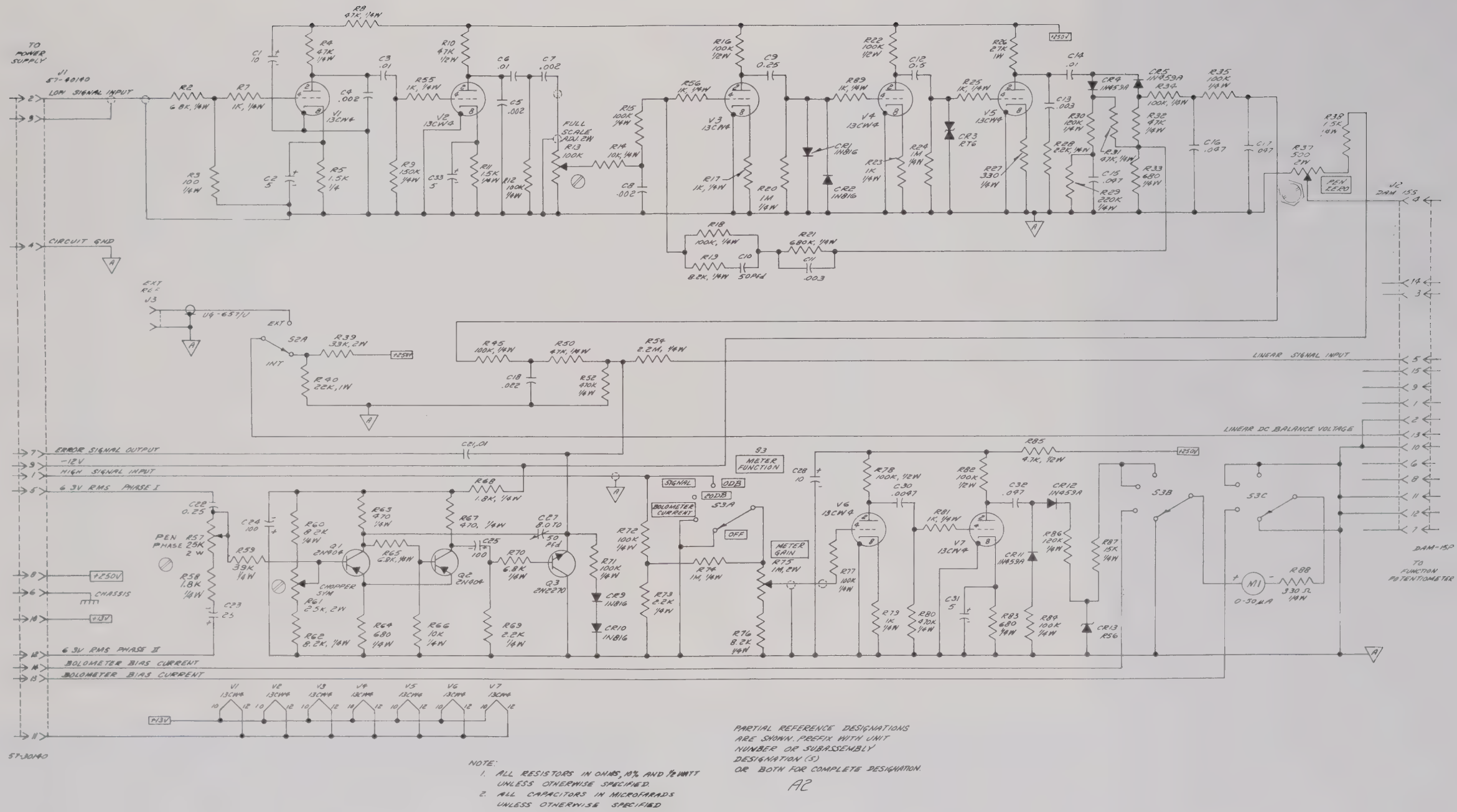
Fig. 7.4.3. Recorder Head Schematic Diagram (Serial No. 198 and up)





R IN OHMS	TYPE	4553-40
R1	1250 ±.1% 1/3W	1440
R2	1250 ±.1% 1/3W	3900
R3	±10% 1/4W COMPOSITION	1500

Fig. 7.5. Plug-In Potentiometers Schematic Diagram



PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. PREFIX WITH UNIT NUMBER OR SUBASSEMBLY DESIGNATION (S) OR BOTH FOR COMPLETE DESIGNATION.

AC

NOTE:
1. ALL RESISTORS IN OHMS, 10% AND ½ WATT UNLESS OTHERWISE SPECIFIED.
2. ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

Fig. 7.6. Linear Pen Function Amplifier Schematic Diagram (Model 1555-1)

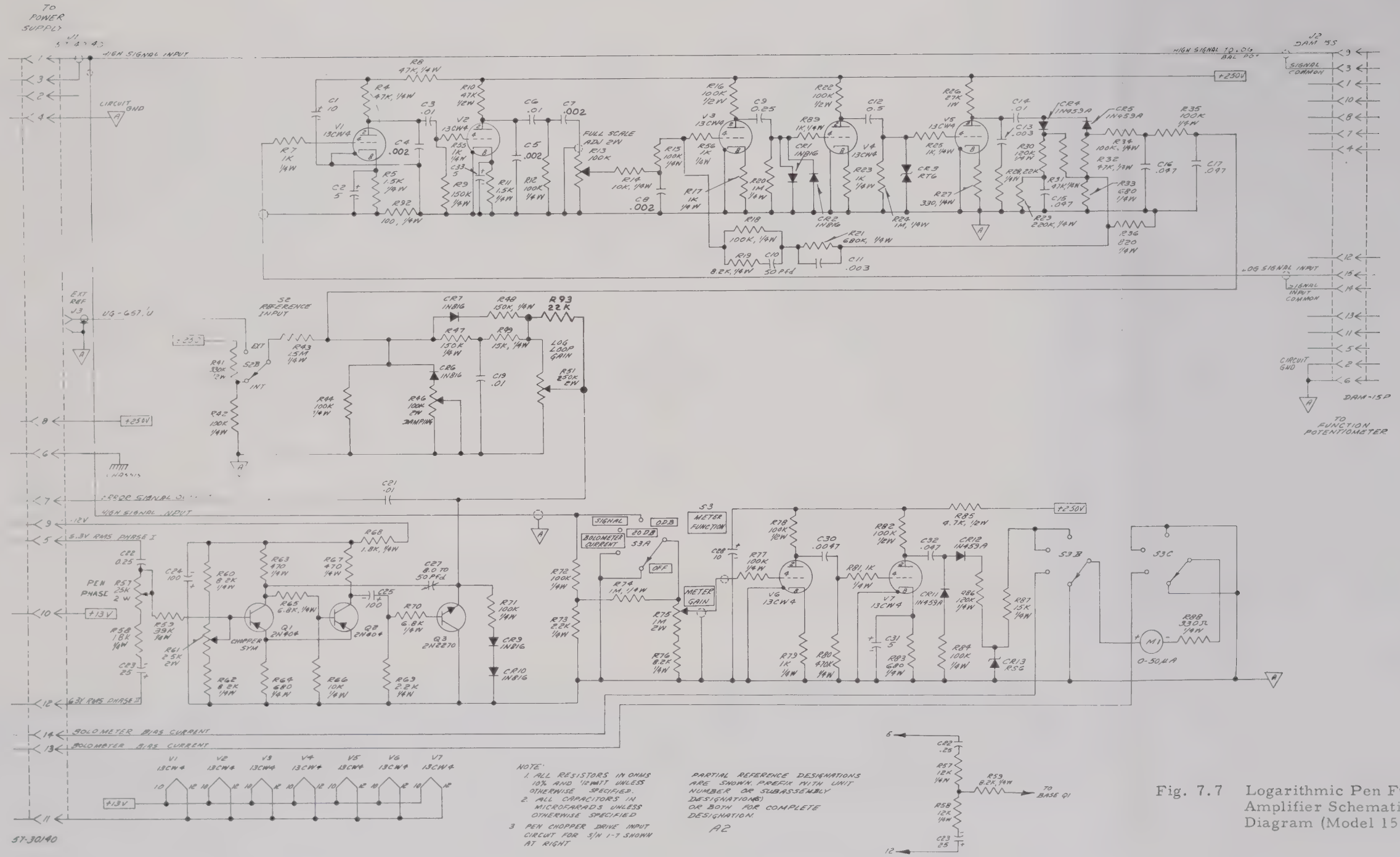


Fig. 7.7 Logarithmic Pen Function Amplifier Schematic Diagram (Model 1555-2)

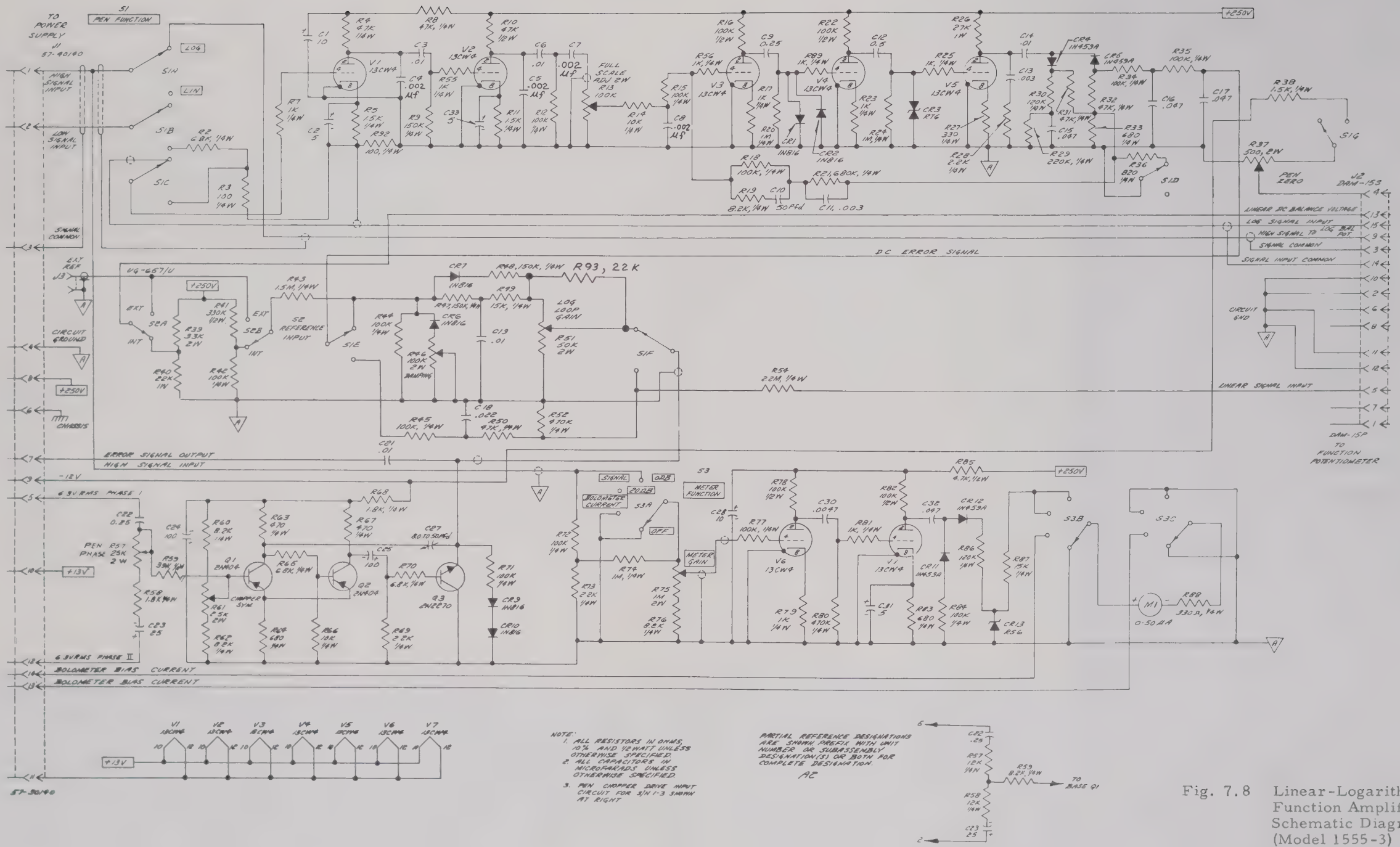
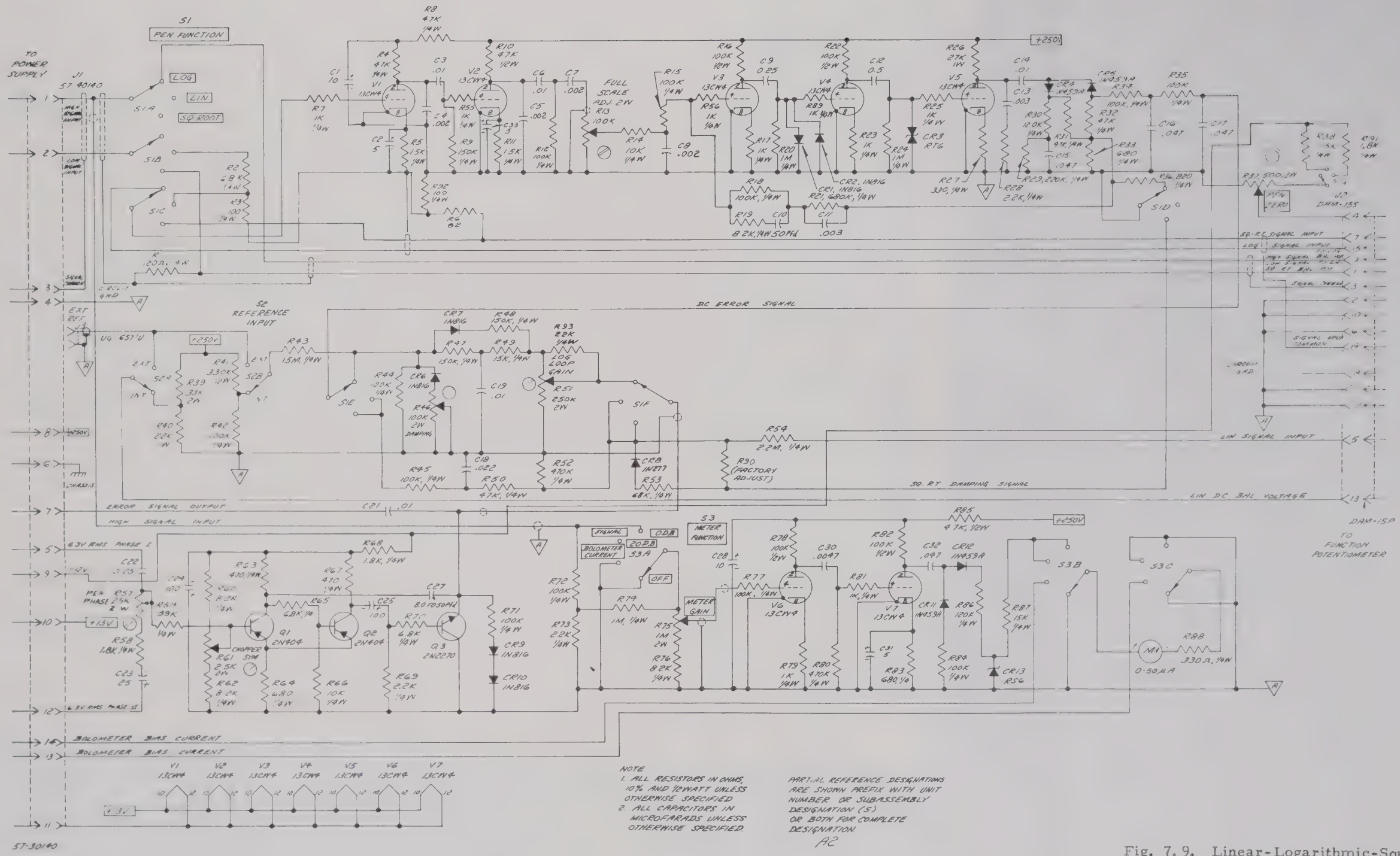


Fig. 7.8 Linear-Logarithmic Pen Function Amplifier Schematic Diagram (Model 1555-3)



NOTE
1. ALL RESISTORS IN OHMS, 10% AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.
2. ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

PARTIAL REFERENCE DESIGNATIONS ARE SHOWN PREFIX WITH UNIT NUMBER OR SUBASSEMBLY DESIGNATION (S) OR BOTH FOR COMPLETE DESIGNATION

AC

Fig. 7.9. Linear-Logarithmic-Square Root Pen Function Amplifier Schematic Diagram (Model 1555-5)

CONVERSION OF VOLTAGE AND POWER RATIOS TO DECIBELS

The basic chart below indicates the number of decibels (dB) corresponding to the listed ratios of voltage or power over the range of −20 to +20 dB. For voltage or power ratios greater than those included in the chart, the ratio can be broken down into a product of two numbers, the value in dB for each found separately, and the two results added. Example: To convert a power ratio of 2,000:1 to dB, express 2,000 as 2×10^3; the number of dB corresponding to a power ratio of 2 is very nearly 3, and the number of dB for a power ratio of 10^3 is 30. Therefore, the power ratio of 2,000:1 is approximately 30 dB + 3 dB = 33 dB. In the lower righthand corner of the chart dB values for voltage and power ratios of integral powers of 10 are given.

Voltage Ratio	*Power Ratio*	*−dB+*	*Voltage Ratio*	*Power Ratio*	*Voltage Ratio*	*Power Ratio*	*−dB+*	*Voltage Ratio*	*Power Ratio*	*Voltage Ratio*	*Power Ratio*	*−dB+*	*Voltage Ratio*	*Power Ratio*
1.000	**1.000**	**0**	**1.000**	**1.000**	**.447**	**.200**	**7.0**	**2.239**	**5.012**	**.200**	**.0398**	**14.0**	**5.012**	**25.12**
.989	.977	.1	1.012	1.023	.442	.195	7.1	2.265	5.129	.197	.0389	14.1	5.070	25.70
.977	.955	.2	1.023	1.047	.437	.191	7.2	2.291	5.248	.195	.0380	14.2	5.129	26.30
.966	.933	.3	1.035	1.072	.432	.186	7.3	2.317	5.370	.193	.0372	14.3	5.188	26.92
.955	.912	.4	1.047	1.096	.427	.182	7.4	2.344	5.495	.191	.0363	14.4	5.248	27.54
.944	.891	.5	1.059	1.122	.422	.178	7.5	2.371	5.623	.188	.0355	14.5	5.309	28.18
.933	.871	.6	1.072	1.148	.417	.174	7.6	2.399	5.754	.186	.0347	14.6	5.370	28.84
.923	.851	.7	1.084	1.175	.412	.170	7.7	2.427	5.888	.184	.0339	14.7	5.433	29.51
.912	.832	.8	1.096	1.202	.407	.166	7.8	2.455	6.026	.182	.0331	14.8	5.495	30.20
.902	.813	.9	1.109	1.230	.403	.162	7.9	2.483	6.166	.180	.0324	14.9	5.559	30.90
.891	**.794**	**1.0**	**1.122**	**1.259**	**.398**	**.159**	**8.0**	**2.512**	**6.310**	**.178**	**.0316**	**15.0**	**5.623**	**31.62**
.881	.776	1.1	1.135	1.288	.394	.155	8.1	2.541	6.457	.176	.0309	15.1	5.689	32.36
.871	.759	1.2	1.148	1.318	.389	.151	8.2	2.570	6.607	.174	.0302	15.2	5.754	33.11
.861	.741	1.3	1.161	1.349	.385	.148	8.3	2.600	6.761	.172	.0295	15.3	5.821	33.88
.851	.724	1.4	1.175	1.380	.380	.145	8.4	2.630	6.918	.170	.0288	15.4	5.888	34.67
.841	.708	1.5	1.189	1.413	.376	.141	8.5	2.661	7.079	.168	.0282	15.5	5.957	35.48
.832	.692	1.6	1.202	1.445	.372	.138	8.6	2.692	7.244	.166	.0275	15.6	6.026	36.31
.822	.676	1.7	1.216	1.479	.367	.135	8.7	2.723	7.413	.164	.0269	15.7	6.095	37.15
.813	.661	1.8	1.230	1.514	.363	.132	8.8	2.754	7.586	.162	.0263	15.8	6.166	38.02
.804	.646	1.9	1.245	1.549	.359	.129	8.9	2.786	7.762	.160	.0257	15.9	6.237	38.90
.794	**.631**	**2.0**	**1.259**	**1.585**	**.355**	**.126**	**9.0**	**2.818**	**7.943**	**.159**	**.0251**	**16.0**	**6.310**	**39.81**
.785	.617	2.1	1.274	1.622	.351	.123	9.1	2.851	8.128	.157	.0246	16.1	6.383	40.74
.776	.603	2.2	1.288	1.660	.347	.120	9.2	2.884	8.318	.155	.0240	16.2	6.457	41.69
.767	.589	2.3	1.303	1.698	.343	.118	9.3	2.917	8.511	.153	.0234	16.3	6.531	42.66
.759	.575	2.4	1.318	1.738	.339	.115	9.4	2.951	8.710	.151	.0229	16.4	6.607	43.65
.750	.562	2.5	1.334	1.778	.335	.112	9.5	2.985	8.913	.150	.0224	16.5	6.683	44.67
.741	.550	2.6	1.349	1.820	.331	.110	9.6	3.020	9.120	.148	.0219	16.6	6.761	45.71
.733	.537	2.7	1.365	1.862	.327	.107	9.7	3.055	9.333	.146	.0214	16.7	6.839	46.77
.724	.525	2.8	1.380	1.905	.324	.105	9.8	3.090	9.550	.145	.0209	16.8	6.918	47.86
.716	.513	2.9	1.396	1.950	.320	.102	9.9	3.126	9.772	.143	.0204	16.9	6.998	48.98
.708	**.501**	**3.0**	**1.413**	**1.995**	**.316**	**.100**	**10.0**	**3.162**	**10.000**	**.141**	**.0200**	**17.0**	**7.079**	**50.12**
.700	.490	3.1	1.429	2.042	.313	.0977	10.1	3.199	10.23	.140	.0195	17.1	7.161	51.29
.692	.479	3.2	1.445	2.089	.309	.0955	10.2	3.236	10.47	.138	.0191	17.2	7.244	52.48
.684	.468	3.3	1.462	2.138	.306	.0933	10.3	3.273	10.72	.137	.0186	17.3	7.328	53.70
.676	.457	3.4	1.479	2.188	.302	.0912	10.4	3.311	10.96	.135	.0182	17.4	7.413	54.95
.668	.447	3.5	1.496	2.239	.299	.0891	10.5	3.350	11.22	.133	.0178	17.5	7.499	56.23
.661	.437	3.6	1.514	2.291	.295	.0871	10.6	3.388	11.48	.132	.0174	17.6	7.586	57.54
.653	.427	3.7	1.531	2.344	.292	.0851	10.7	3.428	11.75	.130	.0170	17.7	7.674	58.88
.646	.417	3.8	1.549	2.399	.288	.0832	10.8	3.467	12.02	.129	.0166	17.8	7.762	60.26
.638	.407	3.9	1.567	2.455	.285	.0813	10.9	3.508	12.30	.127	.0162	17.9	7.852	61.66
.631	**.398**	**4.0**	**1.585**	**2.512**	**.282**	**.0794**	**11.0**	**3.548**	**12.59**	**.126**	**.0159**	**18.0**	**7.943**	**63.10**
.624	.389	4.1	1.603	2.570	.279	.0776	11.1	3.589	12.88	.125	.0155	18.1	8.035	64.57
.617	.380	4.2	1.622	2.630	.275	.0759	11.2	3.631	13.18	.123	.0151	18.2	8.128	66.07
.610	.372	4.3	1.641	2.692	.272	.0741	11.3	3.673	13.49	.122	.0148	18.3	8.222	67.61
.603	.363	4.4	1.660	2.754	.269	.0724	11.4	3.715	13.80	.120	.0145	18.4	8.318	69.18
.596	.355	4.5	1.679	2.818	.266	.0708	11.5	3.758	14.13	.119	.0141	18.5	8.414	70.79
.589	.347	4.6	1.698	2.884	.263	.0692	11.6	3.802	14.45	.118	.0138	18.6	8.511	72.44
.582	.339	4.7	1.718	2.951	.260	.0676	11.7	3.846	14.79	.116	.0135	18.7	8.610	74.13
.575	.331	4.8	1.738	3.020	.257	.0661	11.8	3.890	15.14	.115	.0132	18.8	8.710	75.86
.569	.324	4.9	1.758	3.090	.254	.0646	11.9	3.936	15.49	.114	.0129	18.9	8.811	77.62
.562	**.316**	**5.0**	**1.778**	**3.162**	**.251**	**.0631**	**12.0**	**3.981**	**15.85**	**.112**	**.0126**	**19.0**	**8.913**	**79.43**
.556	.309	5.1	1.799	3.236	.248	.0617	12.1	4.027	16.22	.111	.0123	19.1	9.016	81.28
.550	.302	5.2	1.820	3.311	.246	.0603	12.2	4.074	16.60	.110	.0120	19.2	9.120	83.18
.543	.295	5.3	1.841	3.388	.243	.0589	12.3	4.121	16.98	.108	.0118	19.3	9.226	85.11
.537	.288	5.4	1.862	3.467	.240	.0575	12.4	4.169	17.38	.107	.0115	19.4	9.333	87.10
.531	.282	5.5	1.884	3.548	.237	.0562	12.5	4.217	17.78	.106	.0112	19.5	9.441	89.13
.525	.275	5.6	1.905	3.631	.234	.0550	12.6	4.266	18.20	.105	.0110	19.6	9.550	91.20
.519	.269	5.7	1.928	3.715	.232	.0537	12.7	4.315	18.62	.104	.0107	19.7	9.661	93.33
.513	.263	5.8	1.950	3.802	.229	.0525	12.8	4.365	19.05	.102	.0105	19.8	9.772	95.50
.507	.257	5.9	1.972	3.890	.227	.0513	12.9	4.416	19.50	.101	.0102	19.9	9.886	97.72
.501	**.251**	**6.0**	**1.995**	**3.981**	**.224**	**.0501**	**13.0**	**4.467**	**19.95**	**.100**	**.0100**	**20.0**	**10.000**	**100.00**
.496	.246	6.1	2.018	4.074	.221	.0490	13.1	4.519	20.42		10^{-3}	30		10^3
.490	.240	6.2	2.042	4.169	.219	.0479	13.2	4.571	20.89	10^{-2}	10^{-4}	40	10^2	10^4
.484	.234	6.3	2.065	4.266	.216	.0468	13.3	4.624	21.38		10^{-5}	50		10^5
.479	.229	6.4	2.089	4.365	.214	.0457	13.4	4.677	21.88	10^{-3}	10^{-6}	60	10^3	10^6
.473	.224	6.5	2.113	4.467	.211	.0447	13.5	4.732	22.39		10^{-7}	70		10^7
.468	.219	6.6	2.138	4.571	.209	.0437	13.6	4.786	22.91	10^{-4}	10^{-8}	80	10^4	10^8
.462	.214	6.7	2.163	4.677	.207	.0427	13.7	4.842	23.44		10^{-9}	90		10^9
.457	.209	6.8	2.188	4.786	.204	.0417	13.8	4.898	23.99	10^{-5}	10^{-10}	100	10^5	10^{10}
.452	.204	6.9	2.213	4.898	.202	.0407	13.9	4.955	24.55		10^{-11}	110		10^{11}
										10^{-6}	10^{-12}	120	10^6	10^{12}

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